# IRON AND STEEL ENGINEER

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# New! WIDE STRIP REELS

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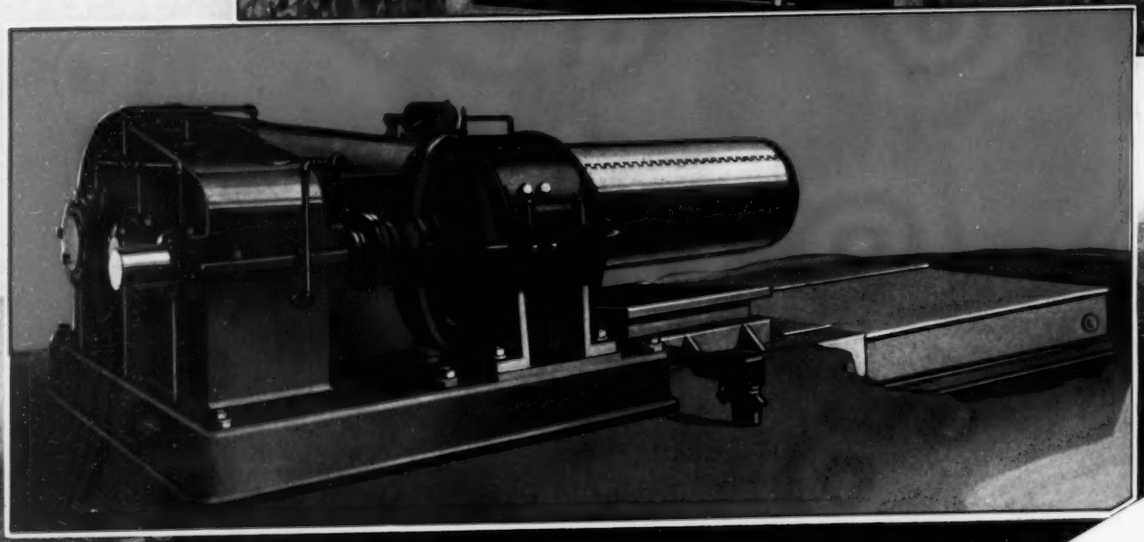

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President of the A. I. & S. E.
Electrical Superintendent
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Aliquippa, Pa.

# G. R. Carroll's Message

## TO MEMBERS OF THE ASSOCIATION OF IRON AND STEEL ENGINEERS

In concluding my term of office as the twenty-ninth president of the Association of Iron and Steel Engineers, I wish to express my gratitude to the Board of Directors and management personnel of the Association for their splendid cooperation during the year past. Without their sympathetic and invaluable support, the head of the organization would find the weight of his duties burdensome indeed, and the progress made in our varied activities during 1935-1936 would not have been possible.

The broad field over which the Association's efforts are spread allows little opportunity to point to specific tangible accomplishments during the comparatively brief period of one year. Furthermore, the future of the iron and steel industry is so filled with the promise for new and greatly improved facilities and methods of development that ordinarily I should hesitate to look back over past achievements of our group, except as a means of providing a goal for future striving.

In this instance, however, I feel that a review of the high points in the Association's history of service during the last 29 years is appropriate, in view of the fact that it was during the past year that the membership took cognizance of the broad scope of the organization's activities in making a change in its official title. The membership voted to drop the word "Electrical" from the previous designation of "The Association of Iron and Steel Electrical Engineers" effective August 1, this year; the Association to be henceforth known as "The Association of Iron and Steel Engineers."

Just as the original aims and activities of the Association broadened and branched out from the early development and study of electrical equipment for steel mills to include many important phases of the iron and steel industry, so the new name eliminates any suggestion of restriction to any one field. The success of the Association in its elected activities is demonstrated by its remarkable growth from a group of some 20 men to a membership international in scope.

In addition to its important contributions to the knowledge and training of iron and steel engineers, it has enriched its members by promoting their association with others having mutual interests and similar aims, and by cementing the bonds of personal friendship between men engaged in the iron and steel industry. The establishment of the National Safety Council, a most important factor in personal relations, is one of its most valued achievements.

While developing a spirit of cooperation among members, it has brought about a closer and more human relationship between men in various divisions of the steel industry and between steel and representatives of companies furnishing the industry with machinery and supplies. It has placed at the disposal of all concerned information obtained through analysis of manufacturing and operating problems, and available sources of information dealing with the latest developments in apparatus and operating methods.

The membership of the Association today is representative of the wider scope of its activities reflected in the recent change of name. It includes the electrical, mechanical, combustion, lubricating, and welding engineering divisions; and the public relations division, all vitally important to the welfare of the industry as a whole. Its past accomplishments are an inspiration as well as a foundation for future growth and service.

Both the art of making steel and the manufacture of steel products have advanced far beyond their early limits, and the Association, intimately associated with this progress must be prepared to cope with the greater and more intricate problems of the future. To be specific, a further development in the finishing departments of hot and cold strip mills, and the ever expanding field of personal relations, are two subjects which offer immediate fields for further achievement.

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# ELECTRIC CONTROL SYSTEMS
## FOR CONTINUOUS STRIP PICKLE LINES

By J. J. MELLON, Sales Engineer
The Clark Controller Company
CLEVELAND, OHIO

**Paper presented before the Cleveland District Section, A. I. & S. E. E., December 13, 1935**

▲ A CONSIDERABLE portion of the large tonnages of strip steel rolled on the continuous hot mills installed within the last few years must be pickled to prepare it for cold reduction, tinning and galvanizing. The surface of the strip steel from the hot mill is covered with scale and other impurities, which will ruin the surface of the finished product unless removed before the strip is put through the process of cold reduction. Essentially the pickling process consists of immersing the strip from the hot mill in a hot sulphuric acid solution for a certain length of time, thus removing the surface impurities. Actually, the continuous pickling methods necessary to handle the large tonnages require a large amount of machinery and need considerable study to provide the desired operation.

Continuous pickle lines in various forms have been operated in mills for several years on narrower widths and light coils, but the recent demand for wide material, and therefore heavy coils, has radically changed the construction and operation of these lines. On installations now in operation the coil widths are up to 84″ and the coils weigh about six tons.

The electric control equipment required for this process is so dependent on the construction and operation of the line, that a considerable portion of this discussion must necessarily cover the mechanical equipment used. Details of the mechanical construction of the machinery, except wherein, they effect the electrical drive, will not be covered in this discussion.

The first type of line to be described will be that as manufactured by the Wean Engineering Company of Warren, Ohio, of which representative installations are now operating in the Detroit and Chicago areas.

Figure No. 1 shows an installation view of two lines of this type, the photograph being taken from a raised platform on the delivery end. It will be noted from this photograph that the machinery at the entry end of the line does not show up at all, due to the length of the line. The average length of these lines is about five hundred feet overall, and this extreme dimension is one of the factors which complicates the design of the drive for these lines.

For purposes of description, the line may be divided into three sections; the entry section, the central or tank section, and the delivery section. Since the central or tank section is the key section of the entire process, it will be described first.

J. J. MELLON

Figure 2 shows the tank section of the line. The proportions of the apparatus have been distorted in order to illustrate the equipment. Actually this section of the line might be about 250 ft. long, and the individual tanks would be about four feet high.

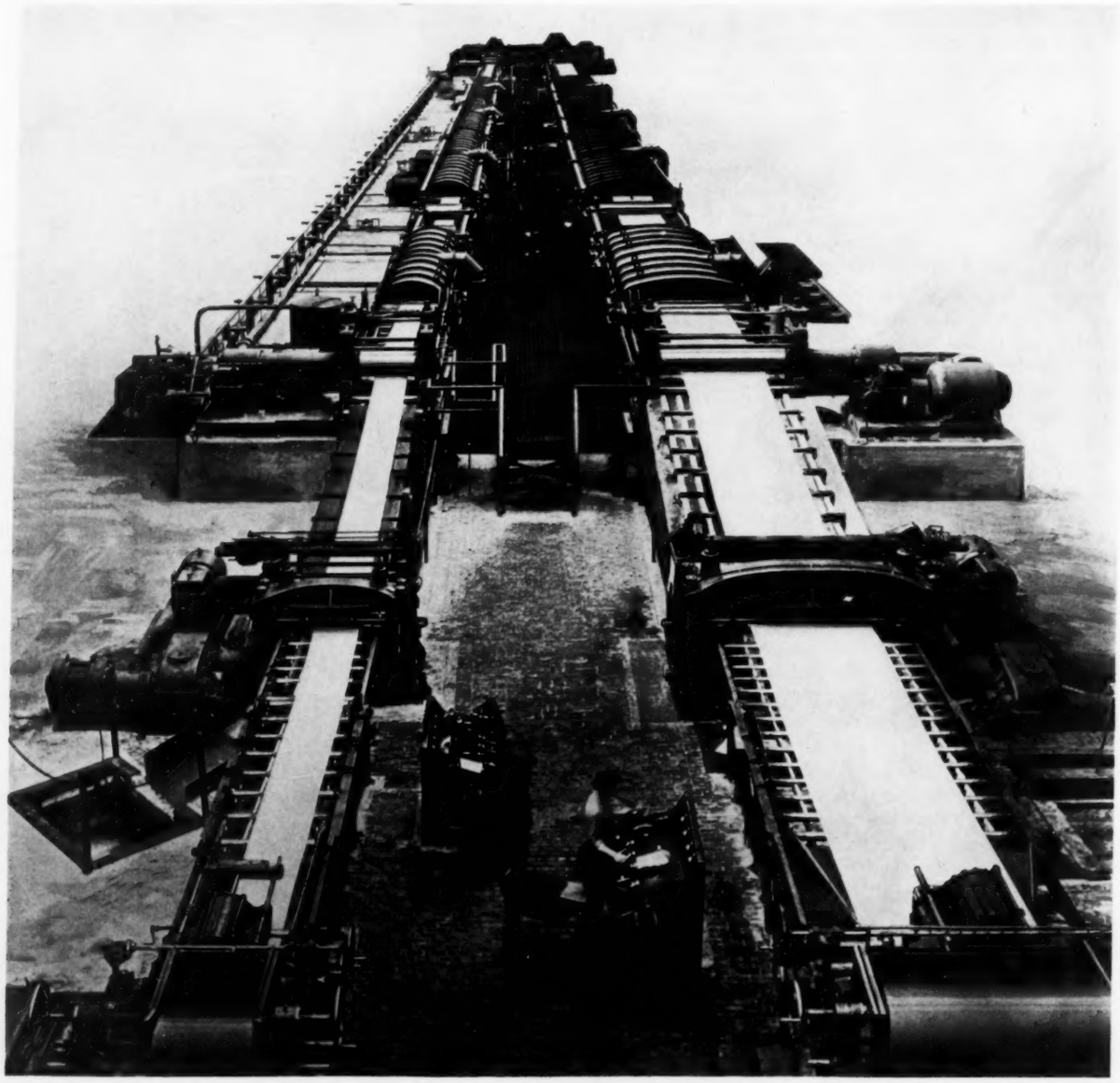
From the illustration, it will be seen that the process consists of running material continuously through the acid tanks, and then the water tanks in tandem, and for a certain strength of acid solution, uniform pickling will be obtained as long as the feed of the material through the acid tanks is at a constant speed. Therefore, any stopping or retarding of the material going through the tank, in order to take care of loading or discharging problems would result in a variation in the uniformity of pickling. This variation, of course, is greater on high speed than it is on the lower speed pickling with the weaker solutions, and whether or

not these fluctuations are sufficient to vary the commercial value of the finished product is beyond the scope of this paper. It should, however, be borne in mind that from the pickling standpoint it is highly desirable to have a uniform and continuous speed of feeding the material through the tanks.

The strip is carried through the tanks by two motor driven pinch rolls; one shown at the left at the entrance to acid tank No. 1, and the other shown at the extreme right on the delivery end of the hot water tank. For convenience the pinch roll at the entry end is called the master pinch roll, and that at the delivery end the follower pinch roll. For 84″ material, the master pinch roll is driven by a 20 H.P., 4/1 speed range D.C. Motor, and the follower pinch roll by a 40 H.P., 4/1 speed range D.C. Motor. The four to one motor speed range is required to take care of different speeds through the tanks, due both to difference in material and variation in the acid solution. It should be borne in mind that with a four to one speed range on the motors, a four to one speed range in running speed through the tanks is not possible because part of the speed range of the follower pinch roll motor is necessary in order to synchronize it with the master pinch roll, but in general a four to one motor speed should give a range of about 3½ to 1 in actual running speed through the tanks.

It is very desirable that the strip level through the tanks be controlled in order to prevent the strip from dragging on the bottom of the tank, and also to pre-

**Fig. 1—Installation of parallel pickling lines of approximately 500 feet length.**



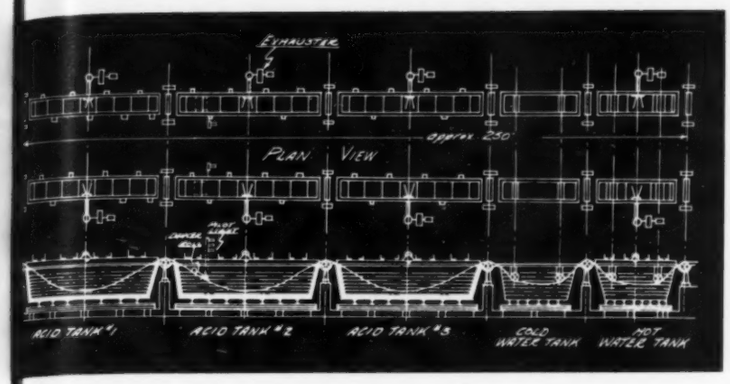



**Fig. 2—Continuous strip pickling line showing front elevation of control or tank section.**

vent breaking of the strip at the stitch if too much tension is placed on it. This means that it is necessary to synchronize the master and follower pinch roll motors.

The rheostats controlling the speed of the master and follower pinch roll motors are controlled from a common operating lever, but due to the fact that there are different loads on the motors, this fact in itself will not keep their speeds in synchronism. To take care of this condition a dancer roll, bearing on the strip in one of the three acid tanks, operates a rheostat in the field of the follower pinch roll motor and causes the motor to speed up and slow down as required in order to maintain a definite strip position. It will be noted that only one dancer roll rheostat is required, even though there are three tanks, since the catenary curve formed by the strip in the tanks is the same in all three.

In addition to this corrective device, it is desirable for the operators of the pickle line to know at all times whether the position of the strip in the tanks is above or below the normal operating position. Since the tanks are covered, it is impossible to observe the position of the strip from outside. Because of this, the dancer roll mechanism also operates a limit switch, lighting a red indicating light when the strip position is high, a yellow light when normal and a green light when lower than normal. These lights are in the form of a traffic signal similar to those used at street intersections, and are visible from both the entry and delivery ends of the line. A duplicate set of these lights, except in the flush mounted switchboard type, are mounted in the control desk at the delivery end so that the delivery end operator can note the position of the strip without looking down the line toward this position indicator.

The control of the speed of material through the tanks is from the delivery end, where the operator can inspect the material being delivered from the line, and determine whether a faster or slower speed of feed of material is necessary to obtain the desired pickling.

A tachometer generator, driven from the master pinch roll, and calibrated in feet per minute, gives an indication on both ends of the line of the speed of the material through the tanks.

A variation in speed of from 35 to 140 feet per minute is normally provided on pickle lines of this type.

The tanks used in many of these installations are of steel lined with rubber and brick. The tank covers are of steel lined with rubber, and all rolls and other parts in contact with the acid are rubber coated.

One exhaust fan is provided for each acid tank and the hot water tank to carry off the acid fumes. With the covers down tight and the exhausters operating, there are hardly any acid fumes in evidence along the line. Figure 3 shows the material passing over a rubber coated roll entering the tanks.

Figure 4 shows a diagrammatic layout of the entry or feeding section of two pickle lines. The purpose of this section is to supply material constantly to the master pinch roll so that it will be unnecessary at any time to retard or stop the passage of material into the tanks.

**Fig. 3—Material passing over a rubber coated roll entering the tanks.**

In general, coils from the hot mill are stored on end near the entry end of the line. These coils are picked up by a crane and deposited on an up-ending device at the entrance to the coil conveyor. This up-ending device, which may be air or motor operated merely places the coil on the feeding conveyor with its axis in the horizontal position. These feeding conveyors are shown in Figure 4. These conveyors provide for gravity feed of the coils to the position immediately in front of the uncoiler and mechanical stops are provided so that the coil can be discharged without interference from other coils. This discharging section of the coil conveyor is provided with an air cylinder tilting mechanism, which causes the coil to roll off and down into the uncoiler when operated.

The uncoiler used in line is of the processing type; that is, it not only uncoils the material but also processes it so that when the material is looped in the water pit, as shown in the sketch, there will be no breaks in the strip, and also the manufacturers claim that the scale is also loosened so as to permit a more rapid action of the acid on the material when going through the tanks, and thus permitting higher pickling speeds.

The main rolls of the uncoiler are driven by a 100/125

H.P., 300/1200 R.P.M. D.C. Motor with reversing dynamic braking control. On some of the more recent installations, motors with a two to one speed range by field control have been provided, and an armature shunt point used to get the inching speeds required.

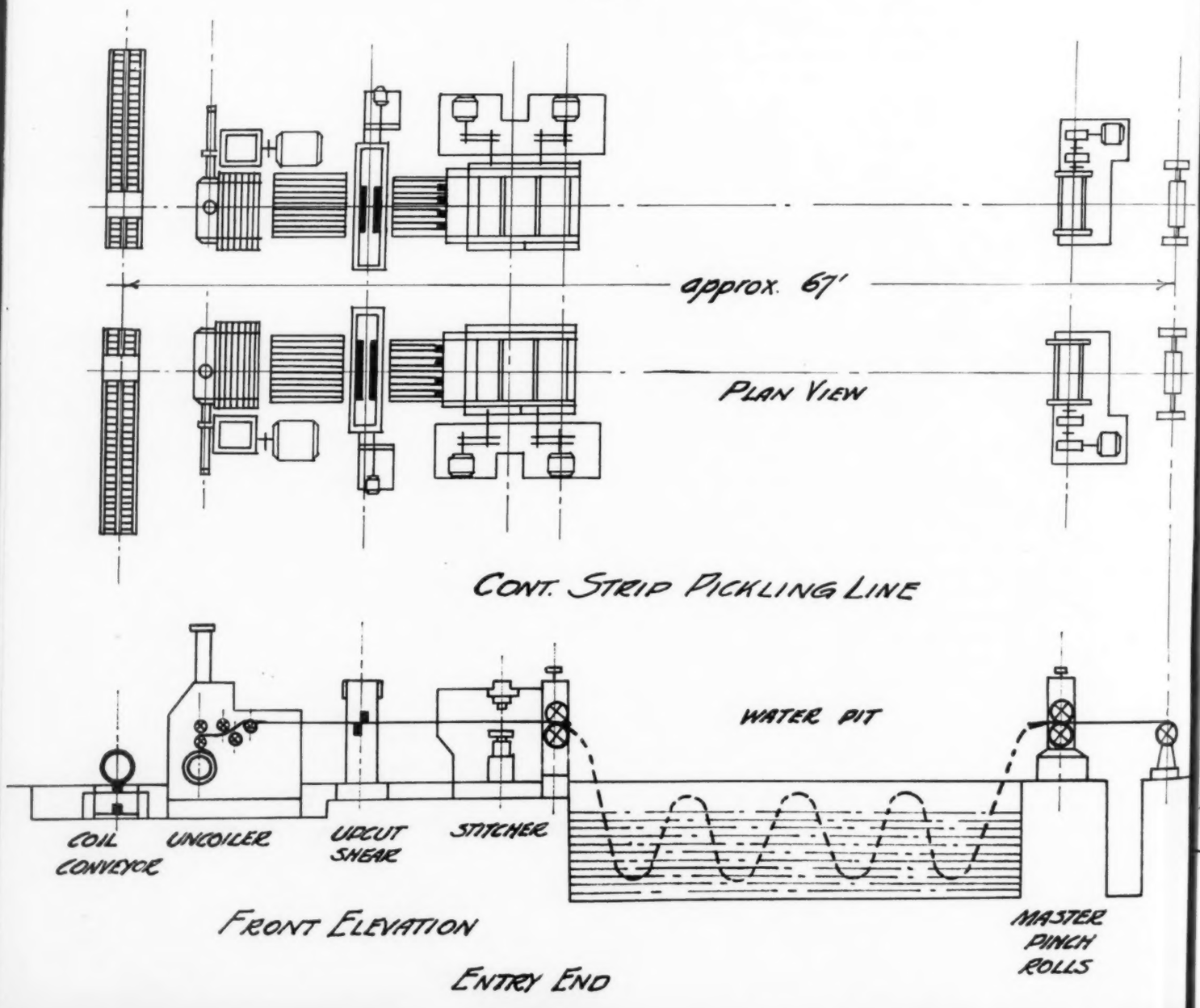
When a coil is discharged from the coil conveyor into the uncoiler, it rests on two rolls called "Cradle Rolls". These rolls are driven by two 5 H.P. squirrel cage induction motors with reversing across-the-line type control, and their purpose is to inch the coil around until the end is in the proper position for entering into the uncoiler main rolls. It should be remembered that this coil weighs about six tons, and the inching has to be done by a motor.

A mandrel is next moved into position in the center of the coil, and this mandrel drive is operated by a 10 H.P. squirrel cage motor with reversing across-the-line type control complete with a magnetic brake and limit switches for stopping the mandrel at both ends of travel.

Another motor is included in the uncoiler to vary the processing, and this also requires a reversing, across-the-line type controller for a squirrel cage motor, magnetic brake and limit switches at both ends of travel.

The next machine shown in the line is the upcut shear. The purpose of this device is to cut off the irregular front end of the entering coil and the irregular rear end of the preceding coil to prepare for the stitching operation. This shear must be so arranged that when the push button is momentarily depressed, it will make one cut and stop. It is necessary that the shear make the complete cycle in approximately one second. Although heretofore, on shears of this type, mill type direct current motors were used, Reliance Electric & Engineering Company have developed and applied A.C. squirrel cage motors to this drive, which gives the necessary high speed operation as well as a more simple motor and control drive. The requirements for high speed, and at the same time relatively frequent operation, caused us to supply a direct current shunt wound brake to this motor for stopping.

Fig. 4



On an A.C. brake of the size required for this job, the operating devices available are of the thrustor, motor operated, or solenoid type. Our experience with A.C. brakes indicated that the thrustor or motor operated brake would be too slow in operation, and a large A.C. solenoid brake would not stand up satisfactorily in service. The D.C. brake of a special fast operating type, together with a geared limit switch and a squirrel cage motor with across-the-line starting, has been a very successful application of this type of shear. The shear motors are, in general, 50 H.P., 500 R.P.M.

The next machine shown is the stitcher, the function of which is to stitch the rear end of the leaving coil and the front end of the oncoming coil so that they can be carried through the tanks as if they were one continuous piece of material. The drive on the stitcher is the same as on the shear except for an increased size due to greater torque requirements. On wide materials, a 75 H.P. squirrel cage motor is usually used.

The next set of rolls shown are the stitcher pinch rolls, which are driven by a D.C. Motor of about 10 H.P. with a four to one speed range. On some of the later installations, the speed range by field control has been reduced to two to one and an armature shunt point has been used to get the low speed inching required. The function of the stitcher pinch roll is to flatten out the stitch and to make possible the inching of the rear end of the outgoing piece into proper stitching position. Since material is in the uncoiler rolls and the stitcher pinch rolls at the same time, it is necessary that the speed of these rolls be synchronized. An air cylinder is provided, which will open these rolls so that they do not bear on the strip for normal operation.

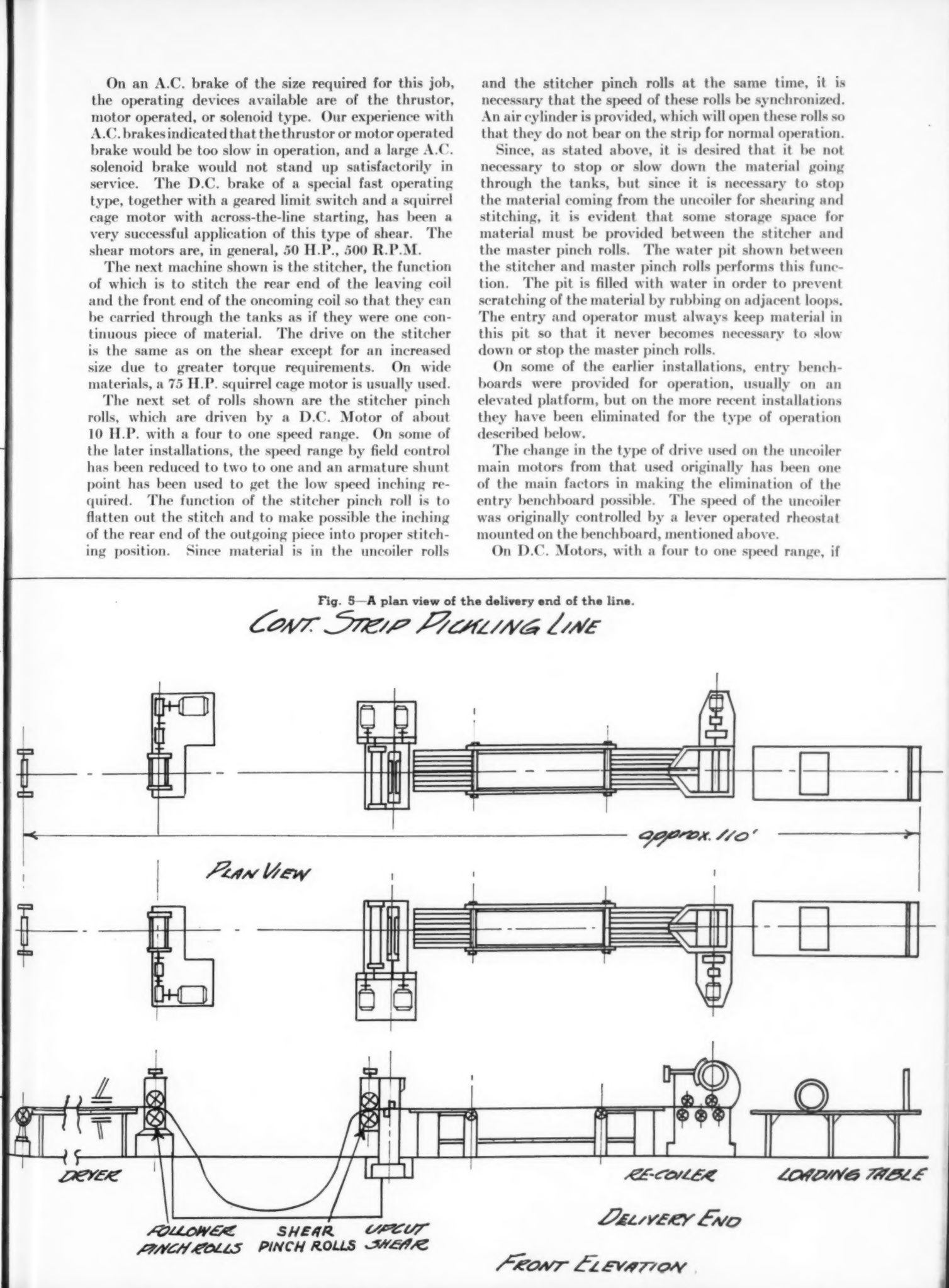
Since, as stated above, it is desired that it be not necessary to stop or slow down the material going through the tanks, but since it is necessary to stop the material coming from the uncoiler for shearing and stitching, it is evident that some storage space for material must be provided between the stitcher and the master pinch rolls. The water pit shown between the stitcher and master pinch rolls performs this function. The pit is filled with water in order to prevent scratching of the material by rubbing on adjacent loops. The entry and operator must always keep material in this pit so that it never becomes necessary to slow down or stop the master pinch rolls.

On some of the earlier installations, entry benchboards were provided for operation, usually on an elevated platform, but on the more recent installations they have been eliminated for the type of operation described below.

The change in the type of drive used on the uncoiler main motors from that used originally has been one of the main factors in making the elimination of the entry benchboard possible. The speed of the uncoiler was originally controlled by a lever operated rheostat mounted on the benchboard, mentioned above.

On D.C. Motors, with a four to one speed range, if

Fig. 5—A plan view of the delivery end of the line.



the motor is running at weakened field or top speed, and the rheostat is brought quickly to the full field position, or a relay functions to apply full field, destructive commutation is experienced. Accordingly, on these motors, field decelerating relays are generally used, which function on high current when strengthening the field too rapidly, and alternately strengthen and weaken the field with a fluttering action, thus bringing the motor down to full field speed without destructive commutation.

On the very large motors on the line, as used on the uncoiler, the low armature resistance combined with high mechanical inertia, makes it impractical to obtain satisfactory commutation with a conventional type decelerating relay. Decelerating relays operate from a rise in current, and by the time the corrective action has taken place on a motor of this size, poor commutation has already been experienced. Experiments have shown that by strengthening the field in a number of steps this difficulty can be overcome. The more steps used the more the commutation is improved, and of course, since a motor operated field rheostat gives a very large number of points, and its speed is uniform, it was used with success for handling the field on the uncoiler motor. While the motor operated rheostat was primarily installed to overcome operating difficulties, some other incidental advantages were obtained which alone would more than justify this application.

In operation, it is often desirable to stop the uncoiler as rapidly as possible. The motor operated rheostat, which was used also, has contacts on it which start and stop the motor. Therefore, whenever it is desired to stop rapidly, the motor operating the rheostat is reversed and this first strengthens the field, giving a uniform application of effective regenerative braking. By the time the rheostat arrives at the off position, the motor speed has already been considerably reduced and then dynamic braking is applied. A lower resistance in the dynamic braking circuit with consequent better braking at the lower speed, is obtained since the dynamic braking is always applied from a reduced speed. This more effective dynamic braking is of considerable advantage when inching the uncoiler to spot the material at the shear or stitcher.

The motor operated rheostat used has a D.C. driving motor, and by means of armature shunting and field shunting of this motor, different speeds may be used in acceleration and deceleration due to the fact that a higher rate of speed of the field rheostat is possible in accelerating than in deceleration for acceptable commutation.

In describing the operation of the entry end, we will assume that material is going through the line as shown in Figure 4. One operator will be standing near the stitcher where he can see the material in the water pit, and he will control the speed of the uncoiler feeding material into the pit. At the position near the coil conveyor, there will be either one or two loaders, depending on the size of the coils, and often two loaders can take care of the loading operation in both lines. The operator at the loading end will see the end of the coil go into the uncoiler, and he places the spring return master switch in the stop position and the uncoiler and stitcher pinch rolls are brought quickly to a stop. If necessary he can inch from a separate inch master, which he has, in order to take the material out of the coil space. As soon as this is done, he operates the mandrel master switch causing the mandrel to be withdrawn from the coil space. When the mandrel is withdrawn, an air valve is operated, causing the section of the coil conveyor opposite the uncoiler to be tilted, causing the coil to roll down into the uncoiler on the cradle rolls. The cradle roll master switch is then operated inching the end of the coil around into position for entering into the uncoiler rolls. The mandrel master switch is operated and the mandrel moves into its position in the center of the coil. The uncoiler inch master switch is now operated by the loader, entering the material into the uncoiler rolls. The loader operator may then operate the processing adjustment to vary the processing of the coil. The stop on the coil conveyor is now dropped and another coil moved into place in front of the uncoiler, ready for loading the next time it is required. Normally this is all that the loading operator has to do, and he is free the rest of the time to either take care of the loading on the other line, and to take care of the loading or up-ending of the coils on the coil conveyor.

Meanwhile, the operator on the line at the stitcher has been busy making preparations for the new coil. As soon as the operator at the stitcher sees the line stop and the end of the material come through the uncoiler, he operates an air valve causing the stitcher pinch rolls to come together, bearing on the strip.

He then inches the stitcher pinch rolls until the end of the strip is in proper position for shearing at the shear. The shear push button is then momentarily depressed causing the shear to make one complete cycle, shearing off the rear end of the strip.

Without leaving his position at the stitcher, the stitcher operator then inches the rear end of the outgoing coil into proper position in the stitcher for the stitching operation. As soon as this is done, the operator can see the front end of the new coil is through the uncoiler, and from the same position, by operating his uncoiler master switch, he inches the uncoiler rolls until the front end of the new piece is in the proper position for shearing, and again he momentarily depresses the shear push button, causing the shear to cut off the front end of the new coil. After the front crop is removed, the uncoiler is then inched until the front end of the new piece is in the proper position in the stitcher for stitching.

The operator now momentarily depresses the stitcher push button, causing the stitcher to make one cycle, stitching the two pieces together, and then automatically stopping. He now operates an air valve, causing the new strip to be clamped in the stitcher. The stitcher pinch rolls are then inched toward the tank to cause the stitch to slip or lock. After the stitch is locked, the uncoiler and stitcher pinch rolls are inched forward together, and the stitch goes through the stitcher pinch rolls, and is rolled down flat. The operator now operates an air valve, causing the stitcher pinch rolls to be opened, as they do not bear on the strip during running operation.

The master switch controlling the motor operated rheostat device for the uncoiler and stitcher pinch rolls

is now placed in the "increase" position, and the uncoiler and stitcher pinch rolls are automatically accelerated to the desired running speed by the stitcher operator.

It should be noted that the operator can accomplish the above operations without leaving the stitcher, since the push buttons, master switches, and air valves described above, are all mounted at a convenient location on the side of the stitcher housing so that the operator can look in at the stitcher and still reach the operating devices for inching the material.

The operator at the stitcher is provided with a locked-down stop button so that if he is unable to keep material ahead of the line in the water pit, due to difficulties with the equipment, or there is something wrong at the master pinch roll, he can depress the hold-down button and stop the master and follower pinch rolls, and it is impossible to start them again unless the hold-down button is released. Whenever this hold-down button is depressed, a red indicating light is lighted on the delivery end to notify the operator that the line has been stopped on the entry end.

Figure 5 shows a plan view of the delivery end of the line. Before going through the follower pinch rolls, the material passes down a table on which is located a dryer. The dryer is operated from a continuously running A.C. squirrel cage motor with across-the-line type starting.

After leaving the follower pinch rolls, it will be noted that there is a pit between these rolls and the shear pinch rolls. Unlike the pit in the entry end, this pit is dry, making it impossible to loop the material or even let it touch the bottom of the pit without scratching.

The first drive shown on the delivery end is the shear pinch rolls, which are driven by a 10 H.P., D.C. four to one speed range motor. The speed of these rolls is synchronized with the speed of the recoiler. The upcut shear is of the same type as the shear explained for the entry end of the line. The function of this shear is to cut out the stitch, which was made at the entry end in the stitcher.

The last drive shown is the recoiler or upcoiler. This is powered by a 50-60 H.P. direct current four to one speed range motor. The function of the drive is to coil the material up again for delivery to the tin mills or cold mills. Both the shear pinch rolls and the recoiler are provided with reversing, dynamic braking control.

The delivery end is operated from a benchboard as shown in Figure 6. This benchboard should be placed between the upcut shear and the recoiler in such a position as to give the operator a very good view of the shear, follower pinch rolls and recoiler.

The operation at the delivery end is as follows. Assume the material is coming through the line and being coiled up, as shown in Figure 5. The operator on the benchboard will notice the stitch coming through the follower pinch rolls, and by operating his lever operated rheostat, controlling the speed of the recoiler and shear pinch rolls, he will speed up these two drives so as to make the loop in the pit as small as possible. The reason for this is that when he has to stop to shear out the stitch, that the loop must have a place in the pit to build up without dragging on the bottom at any time.

**Fig. 6—Type of benchboard used to operate delivery end.**

The benchboard operator then operates an air valve, causing the shear pinch rolls to bear on the strip so that after the cut is made, the material will not fall back into the pit. As soon as the stitch is in the proper position for shearing, the operator momentarily depresses the push button and makes a cut ahead of the stitch. As soon as this first cut is made, the operator located on the elevated platform, near the recoiler, operates his master switch, causing the recoiler to speed up to its maximum speed, thus getting the rest of the coil wound up in the shortest possible time. As soon as he has done this, the coil is discharged onto the loading table. Meanwhile the operator at the benchboard has inched the shear pinch rolls forward and made a cut behind the stitch, thus causing the stitch to drop out. He then speeds up the follower pinch rolls and recoiler, thus causing the end of the new coil to move forward and enter the recoiler. An air valve is next operated, causing the shear pinch rolls to be separated as it is not necessary for them to bear on the strip during ordinary running operation. This operation must be so timed that this can all be accomplished without putting enough material into the dry pit to cause it to drag on the bottom of the pit.

On some installations, the finished coils are banded and wrapped on the loading table, whereas on other installations they are simply discharged from the recoiler onto a conveyor.

On two lines recently installed, drum type coilers were used instead of upcoilers, and variable voltage drives were used on the recoiler and shear pinch rolls in order to take care of the motor speed variation required by the build-up on the coil, and to provide tension while coiling.

On pickle lines as manufactured by the Mesta Machine Company, the control requirements are different in some respects from the line described below, and the essential differences are outlined.

On the uncoiler, instead of the mandrell and cradle rolls, an elevating feed reel platform and conical heads are used to hold the coil. The lifting motion is usually operated by a 12 H.P., D.C. mill motor with reversing armature shunt lowering control equipment. A hatchway limit switch stops the motion in the down direction and a jamming relay in the up direction. The armature shunt in the lowering direction is to take care of the overhauling load. This platform is elevated within its limits by operating a reversing master switch conveniently located at the loading position. The feed reel platform centers the coil with the center of the moving head. The heads are moved together so as to clamp the coil with a 12 H.P., D.C. reversing drive, with limit switches for stopping the travel in the out direction, and the jamming relay to stop it in the "in" position. A spring return master switch is used.

On the shears and stitchers, one or two D.C. Motors are used, and of course, they are compound wound mill type motors and are provided with non-reversing, dynamic braking control, with magnetic brakes and geared type limit switches. The operation from the standpoint of the operator is the same.

On the delivery end there is no shear pinch roll, and the operation generally used is as follows:

When the operator at the delivery benchboard sees the stitch come through the follower pinch rolls, he steps to the shear housing, adjacent to him, and momentarily depresses a slow-down push button, causing the master and follower pinch rolls and the recoiler to slow down to a predetermined speed. When the front end of the stitch approaches the shear, the operator momentarily depresses the shear push button, causing the shear to operate and make two cuts automatically, thus cutting out the stitch. A limit switch is, of course, geared to the shear two to one to permit this double operation.

When the shear knives make the first cut, one cam of the limit switch connected to the shear causes the upcoiler to speed up to its maximum speed, so that the released coil may be coiled quickly. The operator then mechanically discharges the coil onto a coil conveyor.

Meanwhile the shear blades have completed their second cut, and the limit switch causes the master and follower pinch rolls to resume their original speed, by means of an adjustable timing relay, which permits the recoiler to be fully coiled and discharged before being automatically brought down to line speed.

Generally speaking, the atmosphere in the pickle building is usually fairly free of acid fumes. However, in heating up the acid, after a week-end shut-down, and also in cases of difficulty, the covers of the tanks are sometimes removed, and of course, in these instances the exhausters fail to remove the fumes from the building. Over a period of years, these fume conditions would likely be detrimental to small details of control apparatus, and for that reason most operators either mount the control at a remote point, where it will not be subject to the fumes, or take precautionary measures to prevent free circulation of the fumes about the control apparatus.

**Fig. 7—Shows type of enclosure used to prevent contamination from fumes.**

For the control panels themselves, a control room is definitely preferable to individually enclosed panels, due to the fact that many of these panels are interlocked electrically and in case of difficulty, it is much easier to locate the trouble on open type boards than it is on dust-tight enclosed boards. In addition to this, open type control boards are more easily checked for routine maintenance than enclosed dust tight panels.

In some instances, it is impractical to have a separate control room and individual enclosures are used. Figure 7 shows a type of enclosure which has been successfully used on these installations. This enclosure is made of heavy gauge material, adequately braced so that when the door is closed, the enclosure can be made practically fume tight with live rubber gaskets and wing nuts. Normally, it will be noted, the bolts on one side act as a hinge, but by means of lock nuts behind the door, it is possible to individually tighten down the wing nuts even on the hinged side. Tapered locating pins are mounted on the jam side of the door so that when the door is closed, it is automatically slipped into a position where the groove and the wing nut studs line up. This is very important with the heavy doors that are used on this type cabinet.

An indicating light mounted in the panel behind the bulls eye, indicates without opening the door whether or not the overload relays or field protective

relays have operated in that particular controller in case of difficulty.

The ventilated enclosure, shown on top, is used to house the resistors. These resistors are of the edge-wound, non-corrosive type. The front, back and sides, and also top of the enclosure are individually removed to make resistor adjustments. The resistor leads are brought to the top of insulated studs going through the top of the cabinet, and the lower part of these studs are connected to the proper terminals on the panel below. These connections through the top of the cabinet are made in a dust-tight manner. In this way, it is possible to take advantage of providing ventilation for the resistor, and at the same time, not permitting acid fumes to circulate about the rest of the control equipment. The entire enclosure is treated with acid-resisting paint.

The benchboard is located along the line and, of course, it is subjected to whatever acid fumes happens to be in that part of the building. There are a number of rheostats and similar apparatus in these benchboards, and it is highly desirable to keep the acid fumes from circulating freely about these devices. For that reason the benchboards are made as fume tight as possible. Figure No. 6 shows the benchboard, and it will be noted that the sides, front and back are removable, but the removable parts are all gasketed. The devices mounted on the benchboard are also arranged so that the operating handles only are exposed to the fumes. The opening in the top of the board, through which the drum mechanism operating the rheostat moves, is also suitably gasketed below the top of the benchboard to prevent free circulation of the fumes.

As mentioned above, these lines are approximately five hundred feet long, and there is quite a difference of opinion as to where the control panels should be mounted with reference to the line. One thought is that the panels should be mounted in two groups, one group near the entry end controlling those drives on the entry end, and one group near the delivery end controlling those drives. This method involves a minimum length of runs of heavy cable, but it has the disadvantage of maintenance and location of difficulties. Other operators prefer to mount the equipment for the entire line in one control room, centrally located along the line, on the basis that the additional cost of installation incident to the length of feeders, is more than offset by the operating and maintenance advantages. We feel that the mounting of all equipment in one central location is of considerable advantage, and should be generally used.

In the normal operation of this line, it is necessary that the rheostats be operated at least once for every coil. Because of this, heavy duty mill type rheostats should be used, having replaceable buttons, resistor elements and other parts, rather than the conventional type of imbedded rheostat.

Considering the fact that most of these motors are of four to one speed range, having field rheostats and other resistances in the circuit, and with the possibility of long leads between the panels and the field, it seems imperative that field protective relays, to stop the motor in case of field failure before destructive speeds are reached, should certainly be used. One field protective relay will protect on field failure provided there are no grounds, but with the long runs used, we recommend two field protective relays, one at each side of the field, which will give field failure protection regardless of grounds.

A question of operating a tandem line with two or more operators at widely separated positions deserves much consideration. Some users have found that a telephone connection between the two ends of the line is a very desirable feature to explain operating difficulties and to cut down delays. These phones are also convenient for supervisors to give instructions to operators from either end of the line. Since the material is in the acid all the time the line is stopped, it is highly desirable that the line get going again as soon as possible, and if the operators have facilities to isolate the reason for the stopping, they will get the line started much sooner.

Many of the operating principles worked out for pickle lines, from a control standpoint, apply equally well to the many other types of metal treating and coating lines that are now being installed.

# ANALYSIS OF ELECTRIC POWER COSTS

## COMPARING GENERATING AND PURCHASING METHODS

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Carnegie-Illinois Steel Corporation
PITTSBURGH, PA.

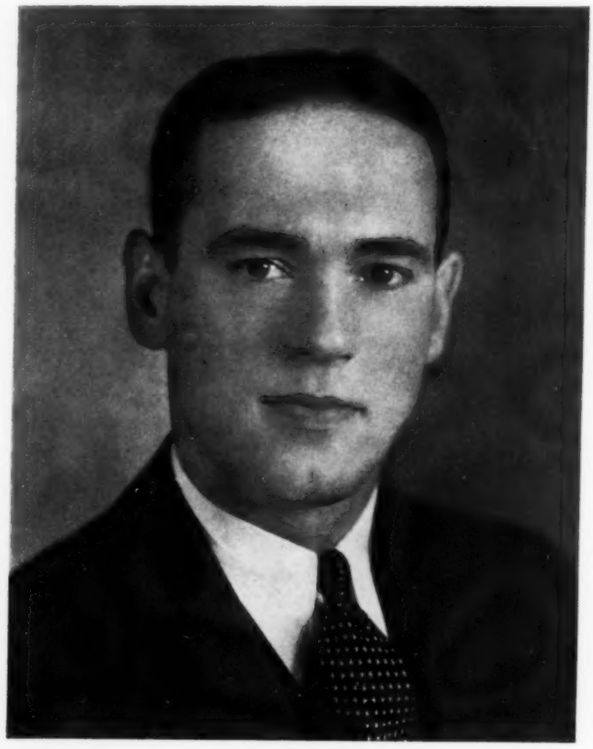
**Paper presented before the A. I. & S. E. E. Chicago District Section Meeting, March 18, 1936**

▲ THE STUDY of comparative power costs for industrial enterprises frequently resolves itself into a comparison of "book costs" or "average costs" that may lead to erroneous answers. If a correct answer is to be found by such a study, it is important that the method of analysis used shall determine what costs will be affected and the relative cost changes that will take place.

For example, in determining the cost of generating power for a mill to be supplied by an additional steam generating unit to duplicate existing units, the normal method might be to determine the average cost per KWH for the existing units over a period of years, and use this as the cost of generating power, perhaps allowing for some increase in efficiencies for more modern design.

This approach can be in error. For example, in the operation of these units, the same supervising staff would probably be used; the turbine room attendants and other similar costs would be only slightly increased, the net result of which would be in "increment cost" on the additional power materially below the previous average. Such an oversight is even more apt to be made in preparing a cost analysis of purchased power, resulting in wide discrepancies between "actual" and "computed" cost. An oversight of this kind may explain why in some cases prime movers have been installed only to be left idle-purchased power being used—and in other cases purchased power has been abandoned necessitating the installation of prime movers.

The object of this paper is to clarify some points of possible confusion. Since analysis of purchased power costs is a much more recent problem to steel mills than analysis of generated power costs, the former has been handled more in detail than the latter, which is only developed sufficiently to show a method of comparison between the two. The point to emphasize is, that analysis of purchased power and of generated power must be made on parallel lines to show true comparative costs. This seems too obvious to warrant mentioning, but, unless it is emphasized, it may frequently be overlooked. As a study of the relative advantages of purchasing or generating power for operating a steel mill is subject to many variables, the discussion will be simplified in this paper by limiting it to a particular problem. It is believed that the method used can be adapted to the solution of other problems, and for this reason is a basis for discussion of the general problem of when to purchase power.



J. W. BATES

### ELECTRICAL LAYOUT OF MILL

To show the background of this study, a single line diagram of the electrical layout of the mill is shown in Fig. No. 1.

Two 132 KV transmission lines supply power to the substation. The substation itself has a main and an auxiliary bus which, by means of a bus-tie breaker and by-pass disconnects permit any breaker to be taken out of service for maintenance without sacrificing

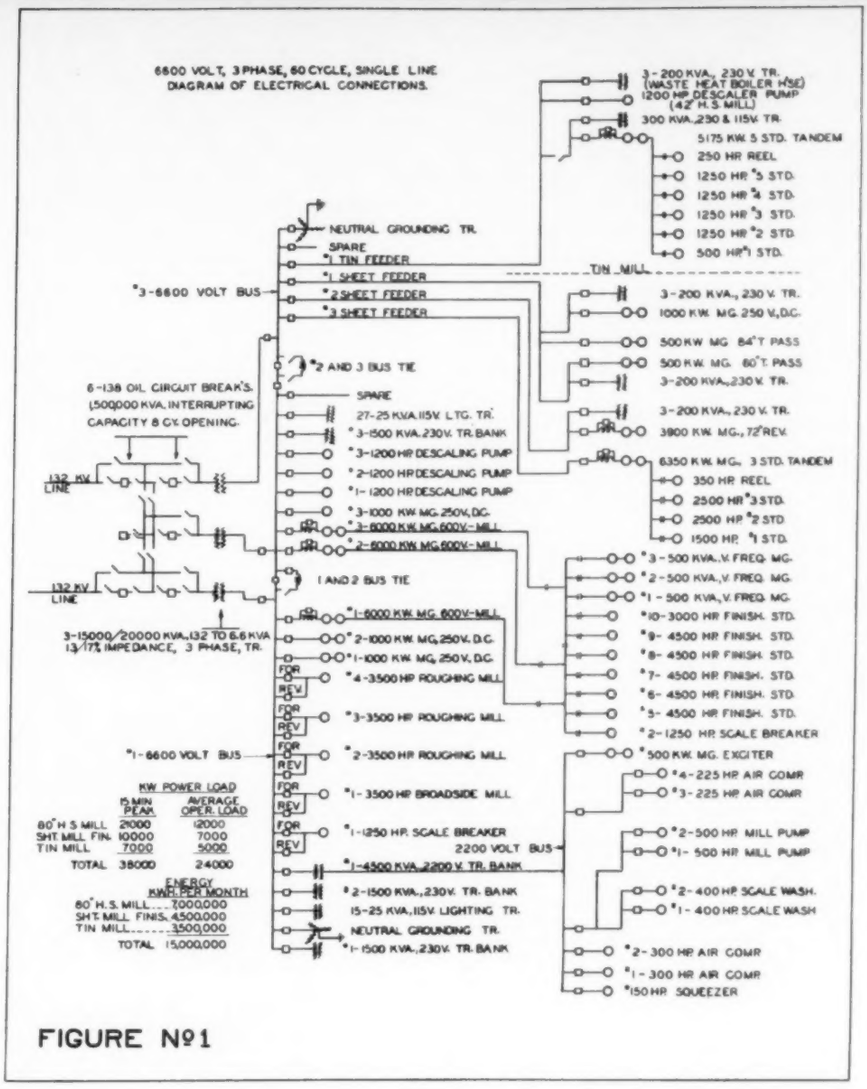

6600 VOLT, 3 PHASE, 60 CYCLE, SINGLE LINE DIAGRAM OF ELECTRICAL CONNECTIONS.
3-200 KVA., 230 V. TR. (WASTE HEAT BOILER HSE)
1200 HP DESCALER PUMP (42" H.S. MILL)
300 KVA. 230 & 115V. TR.
5175 KW. 5 STD. TANDEM
250 HP REEL
1250 HP #5 STD.
1250 HP #4 STD.
1250 HP #3 STD.
1250 HP #2 STD.
500 HP #1 STD.
NEUTRAL GROUNDING TR.
SPARE
#1 TIN FEEDER
#1 SHEET FEEDER
#2 SHEET FEEDER
#3 SHEET FEEDER
TIN MILL
3-6600 VOLT BUS
3-200 KVA., 230 V. TR.
1000 KW. MG. 250 V.D.C.
500 KW. MG. 84" T. PASS
500 KW. MG. 60" T. PASS
3-200 KVA., 230 V. TR.
#2 AND 3 BUS TIE
SPARE
6-138 OIL CIRCUIT BREAKS. 1,500,000 KVA. INTERRUPTING CAPACITY 8 CY. OPENING.
27-25 KVA. 115V. LTG. TR.
#3-1500 KVA. 230V. TR. BANK
3-200 KVA., 230 V. TR.
3800 KW. MG., 72" REV.
#3-1200 HP DESCALING PUMP
#2-1200 HP DESCALING PUMP
#1-1200 HP DESCALING PUMP
6350 KW. MG., 3 STD. TANDEM
350 HP REEL
2500 HP #3 STD.
2500 HP #2 STD.
1500 HP #1 STD.
132 KV LINE
#3-1000 KW. MG. 250V. D.C.
#3-6000 KW. MG. 600V-MILL
#2-6000 KW. MG. 600V-MILL
#3-500 KVA., V. FREQ. MG.
#2-500 KVA., V. FREQ. MG.
#1-500 KVA., V. FREQ. MG.
#10-3000 HP FINISH. STD.
#9-4500 HP FINISH. STD.
#8-4500 HP FINISH. STD.
#7-4500 HP FINISH. STD.
#6-4500 HP FINISH. STD.
#5-4500 HP FINISH. STD.
#2-1250 HP SCALE BREAKER
1 AND 2 BUS TIE
#1-6000 KW. MG. 600V-MILL
3-15000/20000 KVA., 132 TO 6.6 KVA 13/17% IMPEDANCE, 3 PHASE, TR.
#2-1000 KW. MG. 250 V. D.C.
#1-1000 KW. MG. 250 V. D.C.
#4-3500 HP ROUGHING MILL
#3-3500 HP ROUGHING MILL
#1-6600 VOLT BUS
#2-3500 HP ROUGHING MILL
#1-3500 HP BROADSIDE MILL
#1-1250 HP. SCALE BREAKER
2200 VOLT BUS
#500 KW. MG. EXCITER
#4-225 HP AIR COMR
#3-225 HP AIR COMR
#2-500 HP MILL PUMP
#1-500 HP MILL PUMP
#2-400 HP SCALE WASH.
#1-400 HP SCALE WASH
#1-4500 KVA., 2200 V. TR. BANK
#2-1500 KVA., 230 V. TR. BANK
15-25 KVA., 115V. LIGHTING TR.
NEUTRAL GROUNDING TR.
#1-1500 KVA., 230 V. TR. BANK
#2-300 HP AIR COMR
#1-300 HP AIR COMR
#150 HP SQUEEZER
KW POWER LOAD
15 MIN PEAK
AVERAGE OPER. LOAD
80" H.S. MILL 26000 12000
SHT. MILL FIN. 10000 7000
TIN MILL 7000 5000
TOTAL 38000 24000
ENERGY KWH PER MONTH
80" H.S. MILL 7,000,000
SHT. MILL FINIS. 4,500,000
TIN MILL 3,500,000
TOTAL 15,000,000

FIGURE Nº1

circuit breaker protection. The three bays are segregated so that all buses and equipment in any one bay can be cleared and men can work safely without approaching too near to energized equipment.

The line oil circuit breakers of 1,500,000 KVA interrupting capacity are equipped with high speed relays with a maximum operating time of one cycle; the breakers themselves have a maximum time from energizing the trip coil to extinction of the arc of eight cycles. This gives a total time of fault clearance of nine cycles maximum. The 6000 KW motor generator sets are designed to operate for at least ten cycles at 60% voltage on the 6600 volt bus which calculating boards show can be maintained. It is hoped that with this set up faults can occur on either one of the 132 KV lines without resulting in a delay to operations. So

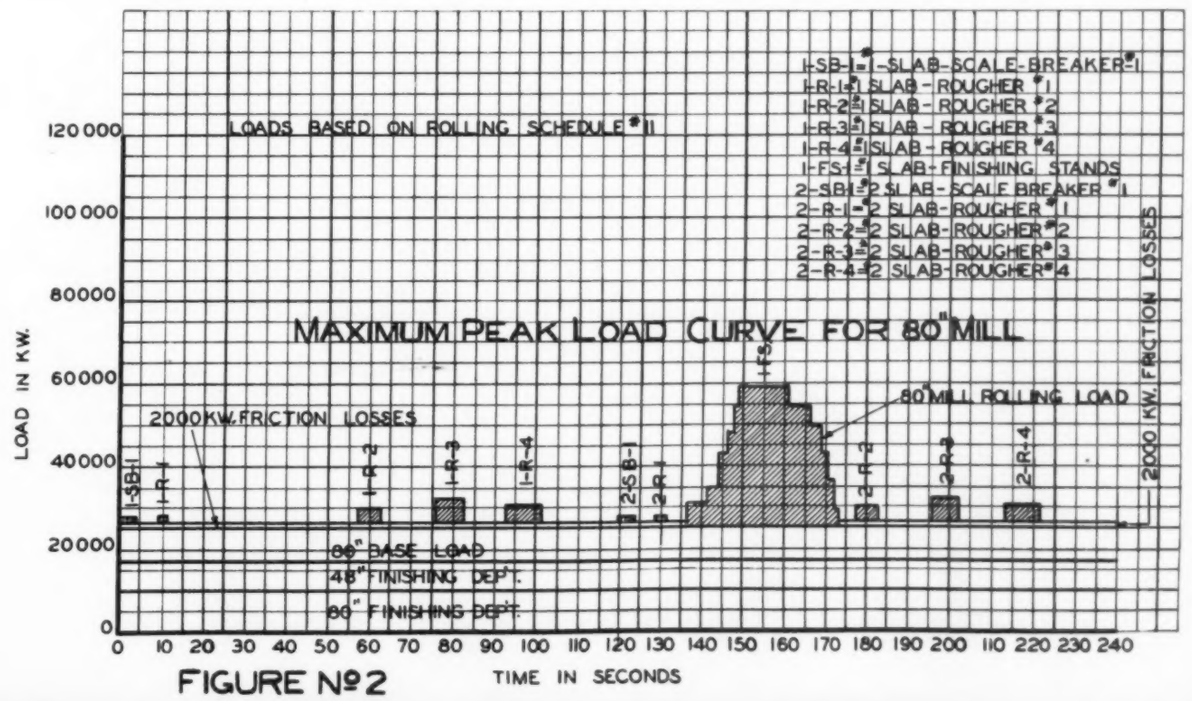



FIGURE Nº2

far as it has been feasible to determine, a short or ground on one of two lines supplying existing mills practically always results in a shut down.

Three 15,000 KVA transformer banks supply a single 6600 volt bus, the bus being split into three sections, the sections being connected together through reactors. This is probably the simplest bus layout obtainable, and by using high reactance transformers (13%) the circuit breakers can be limited to 250,000 KVA capacity. More complicated layouts such as using a synchronizing bus would materially reduce the short circuit current, but not sufficiently to permit the use of the next smaller sized circuit breaker, so that a larger overall investment would result from the use of more complex switching layouts.

To carry the high peak load on the finishing stands it was necessary to use .90 PF drives on the three 6000 KW motor generator sets. During the rolling interval on the finishing stands this results in sufficient leading KVA to offset the reactive KVA required by the induction motors driving the roughing stands. However, during the non-rolling periods sufficient leading KVA is fed into the 6600 volt bus to result in a calculated power factor .70 to .80 leading. This large change in wattless power together with the normal voltage variation on the utility system will result in raising the bus voltage sufficiently to give trouble on the 115 volt A.C. lighting system by causing excessive lamp burnouts.

At this time the extent of the voltage instability is not sufficiently determinated to decide whether the best solution is the installation of voltage regulators on the lighting transformers or the installation of voltage control by means of reducing the motor generator excitation during non-rolling intervals. It is expected that preliminary mill operations will enable sufficient data to be obtained to determine the best method to stabilize the voltage on the 6600 volt bus.

Another interesting electrical detail is the construction of the 600 volt DC bus. This mill has the largest concentration of 600 volt DC power ever put into a steel mill. With the conventional bus layout of two adjacent buses and a calculated short circuit current of from 400,000 to 500,000 amperes at 600 volts, the stresses produced were on the order of 5000 pounds per running foot. To construct a bus rigid enough to stand these stresses was economically prohibitive so that it was necessary to widely separate the buses and use the best possible bus construction at cross overs. The positive bus was arranged on the motor side of the basement and the negative bus on the generator side. With this wide bus separation the stresses are reduced to values that can readily be met and bus distortion encountered on other installations eliminated.

As circuit breakers used on installations having much smaller (200,000 amperes on short circuit) load concentration had given trouble, it appeared desirable to have the manufacturers make all the improvements possible in these devices and test them at 500,000 amperes. This was done, and as most of you know, the three large circuit breaker manufacturers can now offer breakers that they have tested at, or near, these values.

The synchronous equipment is divided between the buses, as far as plant layout will permit, to balance not only the load in KW, but also the "feed in" on short circuit from the synchronous equipment. Under these conditions it is interesting to note that the factor determining the capacity of the circuit breakers is the one-second rating and not the conventional arc interrupting rating.

## LOAD CHARACTERISTICS

You will note that the load is roughly divided into four groups:

1. The 80″ mill rolling load
2. The 80″ mill auxiliary load
3. The 80″ cold mill load
4. The 42″ cold mill load

The character and magnitude of these loads are shown in Fig. No. 2.

These data indicate that all of the loads have good operating characteristics except the 80″ mill rolling load. In this load, peaks of 33,500 KW, lasting 30 to 40 seconds, occur every two minutes. The effect of such peaks on an electrical system, particularly an interconnected utility system, is quite interesting. Some of the utility men will speak on this phase of the problem.

Considering the character of each load we see that the following peaks will have to be carried:

| | |
|---|---|
| 80″ mill rolling peak | = 33,500 KW |
| 80″ mill auxiliary peak | = 8,000 KW |
| 80″ cold mill peak | = 10,000 KW |
| 42″ cold mill peak | = 7,000 KW |
| giving a total short time peak of | 58,500 KW |

Considering these peaks and allowing for slight future additions to the auxiliary load, we arrive at a figure of 50,000 KW of turbine generator capacity required. In order to use an existing generating unit as a spare, ordinarily would require 2—25,000 KW turbines for a steel mill installtion. This is an important consideration, as a single 50,000 KW unit and station can produce power more economically than a station consisting of two 25,000 KW units. Another consideration is, that in order to provide the maximum flexibility in operation of inter-connected steam plants it may mean using relatively low steam pressures.

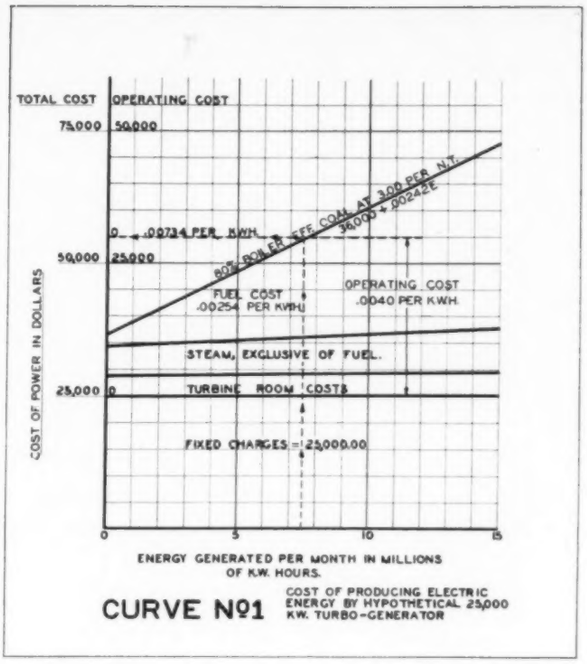
## PLANT GENERATED POWER

On a basis of 50,000 KW of required generating capacity we can now proceed to a study of the cost of supplying this power.

### Investment Costs

The figure of $100.00 per KW of installed capacity is so well accepted by steel mill and public utility engineers that this figure can be used in place of a detailed estimate of the installation costs. In doing this, it is not meant to imply that a detailed estimate of the investment cost should not be made in preparing an actual study of comparative costs.

Curve No. 1 is a graphic representation of the cost of producing power on a 25,000 KW turbine generator. For the purpose of this discussion, the turbine room




**CURVE Nº1** COST OF PRODUCING ELECTRIC ENERGY BY HYPOTHETICAL 25,000 KW. TURBO-GENERATOR

and steam exclusive of fuel costs were selected to show an operating cost of 4 mills per KWH. The fixed charges are shown as $25,000.00 per month. This is calculated on the basis of an investment of:

$100.00 per KW x 25,000 = $2,500,000.00

Fixed charges @ 12% per year or 1% per month = $25,000.00 per month

The 12% fixed charges are divided as follows:

| | |
|---|---|
| Interest | = 5% |
| Depreciation | = 5% |
| Taxes and Insurance | = 2% |
| Total | = 12% |

These fixed charges can be determined for any particular company and may vary slightly over a period of time; for instance at the present time 5% interest may be slightly too high; on the other hand, taxes may exceed the amount shown if the present tendency toward increased taxation continues.

## Operating Costs

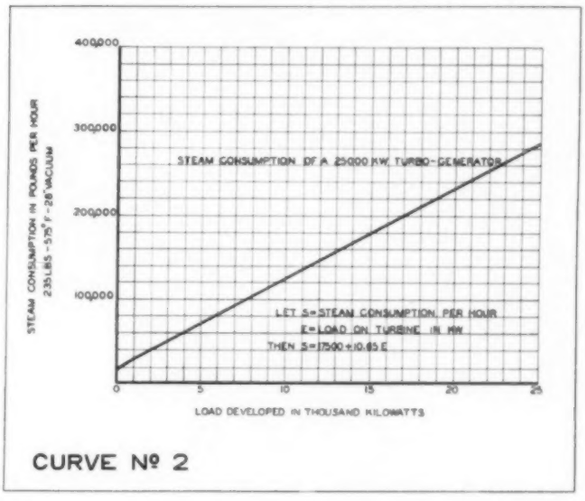
In order to plot the constant and variable portions of the turbine room costs, and steam exclusive of fuel costs, tables No. 1 and No. 2 were prepared.

Table No. 1 shows the method used to separate the constant and variable cost items in a boiler house. The actual costs per BHP month are omitted. This is done to avoid confusion and possible error. Obviously if 1000 BHP months per month are produced in a given boiler house, the cost of superintendence will be exactly double per BHP month the cost of superintendence if the same boiler house produces 2000 BHP months per month. Actually, the total cost in dollars should be set up, the production in BHP months determined for the particular installation, and these values used.

Table No. 2 shows the same data as Table No. 1, only in this table the turbine generators are considered instead of the boilers.

These tabulations, are considered of importance as it represents the opinion of a number of operating engineers on the relative percentages of fixed and variable costs, and in addition, illustrates the method used in arriving at the data shown in Curve No. 1.

To determine the fuel cost, the total steam consumption of a 25,000 K.W. turbine was plotted against the load in curve No. 2. The normal 1/2, 3/4, 4/4 points being exterpolated to zero load, 17,500 lb. of steam was found to be the "constant" or no load consumption of the unit with a rate of 10.65 lb. per KWH, which corresponds to 13,650 B.T.U. These are normal expectancy values and are higher than guarantee rates by a small amount, based on operating data from 15,000 KW units. The amount of steam shown on curve No. 2, when multiplied by the "variable" portion of the steam cost found in Table No. 1, supplies the figures plotted as fuel cost in Curve No. 1.




**CURVE Nº 2**

The sum of the fixed charges, turbine room costs, steam exclusive of fuel, and fuel costs, gives the final value of the total cost of producing power, shown to be .00734 per KWH for 7,500,000 KWH per month.

The cost equation for generating power on a 25,000 KW unit under the conditions shown can now be written as:

Monthly cost = $36,600.00 + .00242E, or for two 25,000 KW units as:

Monthly cost = $73,200.00 + .00242E where $73,200 is the total fixed charge and .00242E is the "increment cost" per KWH.

## UTILITY RATE STRUCTURES

Having determined the cost of plant generated power, it is necessary to learn the cost of purchased power. The local Utility will offer a rate showing the average cost per KWH for the estimated load factor. However, it is necessary to analyze this cost per KWH carefully as most utility rates are complex. This complexity of rates is due, in most part, to a need on the part of the utility to protect itself against losses caused by un-

## COST OF PRODUCING STEAM

HYPOTHETICAL BOILER HOUSE OF 50,000 BO. H. P. CAPACITY
TABULATION SHOWING METHOD OF SEPARATING CONSTANT AND VARIABLE ITEMS

| Col. No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Line No. | Item | Cost in % | | Cost per Bo. Hp. Mo. | | |
| | | Variable | Constant | Total | Variable | Constant |
| | PRODUCING LABOR | | | | | |
| 1 | Superintendence | 0 | 100% | | | |
| 2 | Unloading fuel for immediate use | | | | | |
| 3 | Delivery (stock pile to boilers) | | | | | |
| 4 | Crushing | 10% | 90% | | | |
| 5 | Delivery (crusher to hopper) | | | | | |
| 6 | Firemen | 0 | 100% | | | |
| 7 | Labor for ash disposal | 0 | 100% | | | |
| 8 | Water tenders | 0 | 100% | | | |
| 9 | Boiler washers and cleaners | 50% | 50% | | | |
| 10 | All other producing labor | 0 | 100% | | | |
| | REPAIRS AND MAINTENANCE | | | | | |
| 11 | Stockers, grates, burners, etc. | 50% | 50% | | | |
| 12 | Boilers and fittings | 50% | 50% | | | |
| 13 | Boiler settings | 50% | 50% | | | |
| 14 | Steam mains and pipe coverings | 0 | 100% | | | |
| 15 | All other repairs and maintenance | 10% | 90% | | | |
| | MISCELLANEOUS EXPENSE | | | | | |
| 16 | Tools, lubricants, etc. | 0 | 100% | | | |
| 17 | Water, (exclusive of feedwater) | 0 | 100% | | | |
| 18 | Elec. current, (excl. of auxs.) | 0 | 100% | | | |
| 19 | Yard switching | 0 | 100% | | | |
| 20 | Laboratory expense | 0 | 100% | | | |
| 21 | Shop expense | 0 | 100% | | | |
| 22 | Accident and hospital fund | 0 | 100% | | | |
| 23 | TOTAL WATER PURIFICATION COST | 75% | 25% | | | |
| 24 | Cost Per Bo. HP. Mo. (Exclusive of fuel) | 30%* | 70%* | | | |
| 25 | Cost of fuel per Bo. HP. Mo. | 90% | 10% | | | |
| 26 | GRAND TOTAL HYPOTHETICAL COST OF STEAM PER BO. HP. MO. | 74%* | 26%* | | | |

*Calculated values.

Fuel used per boiler hp. month = $\frac{33{,}479 \times 730}{13{,}000 \times .8 \times 2{,}000}$ = 1.17 tons.

Cost of fuel per bo. hp. mo. assuming coal at $3.00 per gross ton = $3.00 x 1.17 = $3.51.

TABLE No. 1

foreseen changes in conditions affecting the amount of power used, or the characteristics of the load.

Whenever such changed conditions cause losses to the utility, the utility is, of course, entitled to a proper charge. However, the purchaser is sometimes heavily penalized for his failure to analyze, in advance, the load conditions under which he may operate, and determine, together with the utility, whether or not there is justification for the inclusion of the penalty clause in the proposed contract.

Therefore, a proposed rate should be studied closely so that a rate can be agreed upon giving both parties maximum benefits, as only in this way can the contract be economically sound.

## COST OF PRODUCING ELECTRIC ENERGY

HYPOTHETICAL GENERATING STATION OF 50,000 KW. INSTALLED CAPACITY
TABULATION SHOWING METHOD OF SEPARATING CONSTANT AND VARIABLE ITEMS

| Col. No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Line No. | Item | Cost per 1,000 Kw. Hrs. | Cost in percent | | Cost per 1,000 Kw. Hrs. | |
| | | | Variable | Constant | Variable | Constant |
| | PRODUCING LABOR | | | | | |
| 1 | Superintendence | | 0 | 100% | | |
| 2 | Engineers, pilers, wipers, etc. | | 0 | 100% | | |
| | REPAIRS AND MAINTENANCE | | | | | |
| 3 | Buildings and roofs | | 0 | 100% | | |
| 4 | Turbines and auxiliaries | | 25% | 75% | | |
| 5 | Generators and switchboards | | 25% | 75% | | |
| 6 | Cranes and miscellaneous machinery | | 0 | 100% | | |
| | TOOLS, LUBRICANTS, MISC. SUP. | | | | | |
| 7 | Lubricants | | 12½ | 87½ | | |
| 8 | Waste and packing | | 12½ | 87½ | | |
| 9 | Tools | | 12½ | 87½ | | |
| 10 | Miscellaneous general supplies | | 12½ | 87½ | | |
| | INCIDENTALS | | | | | |
| 11 | Yards and switching | | | | | |
| 12 | Laboratory expense | | | | | |
| 13 | Auto trucks | | 0 | 100% | | |
| 14 | General shop expense | | | | | |
| 15 | Accident and hospital fund | | | | | |
| 16 | Misc. lost steam | | | | | |
| 17 | CONDENSER WATER | | 0 | 100% | | |
| 18 | SUB—TOTAL | | 7% | 93% | | |
| | STEAM, EXCLUSIVE OF FUEL | | | | | |
| 19 | Net steam used by turbine | | 30% | 70% | | |
| 20 | Steam used by auxiliaries (15%) | | 30% | 70% | | |
| 21 | SUB—TOTAL | | 20% | 80% | | |
| | FUEL USED FOR STEAM | | | | | |
| 22 | Fuel for net steam to turbine | | 87% | 13% | | |
| 23 | Fuel for steam to auxiliaries (15%) | | 50% | 50% | | |
| 24 | TOTAL | | 59% | 41% | | |

TABLE No. 2

To illustrate, we will examine several types of rates offered by several of the large utilities.

Graphic analysis of rates:—

"A"
"B" Fig. No. 3
"C"

It can be seen that there is a large difference in the cost of power under these schedules. Part of this difference can be explained as being due to availability clauses representing different operating conditions of the utility, and part as being due to the "separate provisions" contained in each rate.

### SEPARATE PROVISIONS

It is impractical to consider all of the separate "provisions" that occur in power contracts. A study of several will serve to illustrate the importance that they can play.

#### 1. INSTANTANEOUS DEMANDS

Some rate schedules contain provisions for billing instantaneous demands on the same or some modified basis as the regular 15 or 30 minute billing demand. Curve No. 3 shows that billing for 20,500 KW of instantaneous peaks would add approximately $36,900 per month, to the cost of purchased power for the contract previously discussed. It would be poor

judgment for a power purchaser to consider a contract containing this provision when operating with the type of load shown.

Whether or not a charge for these peaks is justified depends upon several factors, probably the most important being the normal load swings on the particular utility system. However, if these load swings are well within the normal swings on the utility system, plus a small usage of the "hot" spare generator, the purchaser would appear to be penalized unjustly. Actual experience of some of the utility companies supplying this type of load indicates that a great part of the swings are absorbed by their interconnections with other utilities and warrant no charge for instantaneous peaks.

### 2. Minimum Bills

By including a minimum bill in a power rate the utility is attempting to protect itself against absorbing the fixed charges on the investment made to supply the particular load covered by the contract.

The standard method of doing this (if any one method can be called standard) is to charge a specified amount per KW of the highest billing demand created during a specified period, frequently for either the preceeding 11 months or for the elapsed life of the contract.

In a hypothetical case if we assume a normal demand of 38,000 KW with one peak of 50,000 KW during the preceding 11 months at a minimum charge of $1.25 per KW of demand, the minimum *monthly* bill will be $62,500.00. Suppose a shut down occurred and continued for three months with practically no power usage; the purchaser would have paid 3 times $62,500.00 or $187,500.00 for power that he did not receive. If for the ensuing nine months power purchases were sufficiently above normal to equal a full year's usage, the power company would receive a normal year's pay plus $187,500.00 which would represent an outright loss to the purchaser of $187,500.00.

This could be avoided by setting up a minimum annual bill in dollars.

### 3. Off Peak Clauses and The Use of Constants in Rates

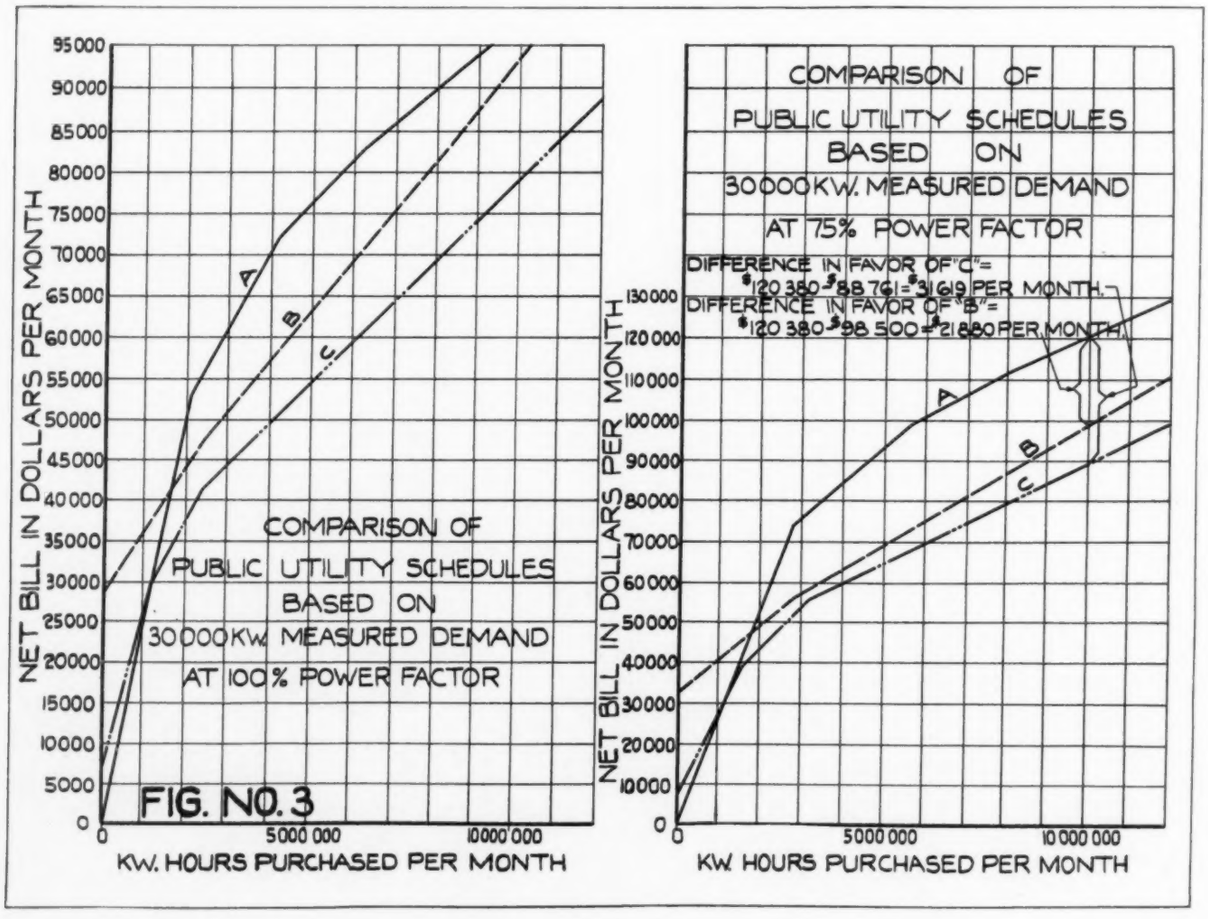
Utility rates normally take the form:

Monthly Bill = C + AD + BE

where C is a constant in dollars
A is the cost per KW of Demand
D is the Demand in KW or KVA
B is the cost per KWH of energy
E is the total energy in KWH

The constant C represents a fixed sum of money payable each month, which is beyond control of the purchaser. The utility rate department does not arbitrarily work out a rate using this formula and inject a large constant. The rate is evolved by various methods to give a certain cost per KWH under specified load conditions. In many cases the method used to plot the rates does not show the existence of the constant. However, it is definitely there.

Comparing two hypothetical rates giving the same average cost per KWH at a specified load:



(1) $30,000.00 + 1.00D + .003E
(2) $ 2,000.00 + 1.90D + .003E

In the case of power purchases in case (1), there is a $30,000.00 monthly charge that cannot be reduced. The peak can be reduced, the energy consumption can be reduced, but relatively small reductions in the bill will be secured, as the $30,000.00 remains payable each month as before.

Case (2) offers the purchaser substantial inducements to reduce his peak loads, thus benefiting both the customer and the utility, and a maximum of overall economic usage of the equipment results.

To illustrate this: If it were possible by making a moderate investment to reduce the peak 10,000 KW, in case (1) the customer would save 10,000 x $1.00 or $10,000.00 per month, while in case (2) the saving would be 10,000 x $1.80 or $18,000.00 per month. This does not mean a loss to the utility, rather, on close analysis it will be found that over a period of time the utility gains, since the most profitable power it can sell is a high "load factor" load.

For this reason it is desirable to eliminate as far as possible the fixed amounts of money payable each month over which the purchaser has no control. The purchaser, therefore, automatically will be offered high inducements to reduce his peaks.

## COST OF PURCHASED POWER

To arrive at a comparative cost of purchased power for the installation under discussion, assume a power rate as follows:

Demand: The first 10,000 KW of Demand @ $2.00 per KW
All over 100,000 KW of Demand @ $1.80 per KWH

Energy: $0.003 per KWH

To visualize power rates more readily it is advisable to reduce them to a graphic form. As previously mentioned, most rates take the following form:

Monthly Bill = C + AD + BE

where C is a constant in dollars
A is the cost per KW of demand
D is the demand in KW or KVA
B is the cost per KWH of energy
E is the energy used in KWH

Applying this to the rate given we have:

For Demands below 10,000 KW
Monthly Bill = $2.00D + .003E

For Demands above 10,000 KW
Monthly Bill = $2,000.00 + 1.80D + .003E

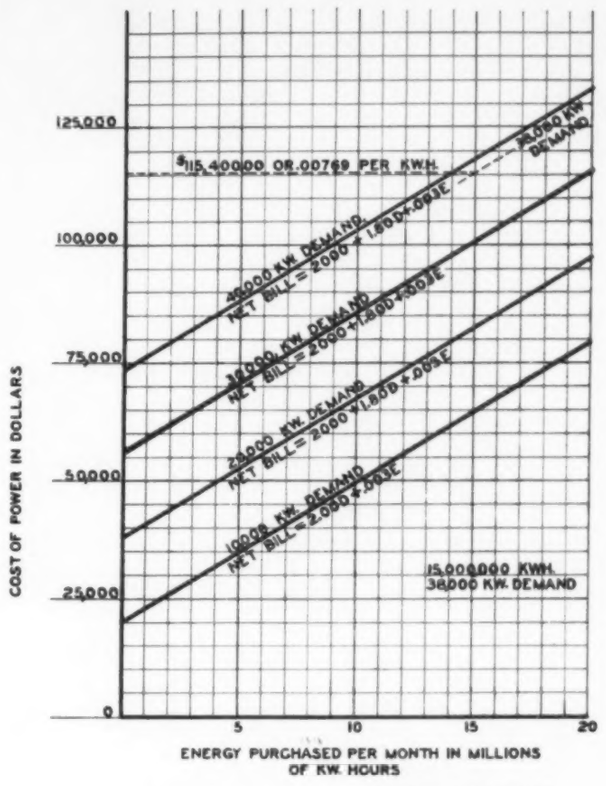
The constant of $2,000.00 is arrived at by taking the difference in demand cost above 10,000 Kw and multiplying it by the demand as:

(2.00 — 1.80) x 10,000 = $2,000.00

This is shown in Curve No. 3.

## COMPARATIVE COSTS OF GENERATED AND PURCHASED POWER

Cost of Generated Power = $73,200.00 + .00242E (1)
Cost of Purchased Power = $2,000.00 + 1.80D + .003E (2)




**CURVE No 3** GRAPHIC ANALYSIS OF PURCHASED POWER ON RATE NO. 1

## COSTS UNDER NORMAL FULL OPERATION

Substituting in (1) and (2)

Monthly cost of:

Generated Power = $73,200.00 + (.00242 x 15,000,000) = $109,500.00

Purchased Power = $2,000.00 + (1.80 x 38,000) + (.003 x 15,000,000) = $115,400.00

Monthly saving by generating power = $5,900.00

Net annual return on investment = $\frac{12 \times 5,900}{5,000,000} = 1.4\%$

Gross return = 12 + 1.4 = 13.4%

## PARTIAL OPERATIONS

Cost of generated power = $73,200.00 + (.00242 x 8,000,000) = $92,560.00

Cost of purchased power = $2,000.00 + (30,000 x 1.80) + (.003 x 8,000,000) = $90,000.00

Monthly loss by generating power = $2,560.00

## SHUT DOWN

Cost of generated power = $80,000.00 + (.00254 x 150,000) = $80,383.00

Cost of purchased power = $57,000.00

Summarizing:

Generating power results in:

Under normal full operations a net return of 1.4%

Under partial operation a loss of $2,560.00 per month

Under shut down a loss of $23,383.00 per month

This would indicate that purchased power should be recommended.

Assumed operating conditions:

| | Per cent operations | KW Demand | KWH used monthly |
|---|---|---|---|
| Normal full operations | 80—100 | 38,000 | 15,000,000 |
| Partial operations | 50 | 30,000 | 8,000,000 |
| Shut Down | 0 | 1,000 | 150,000 |

For purposes of studying the general situation, it may be interesting to see what the comparative costs would be under conditions of high load factor, with small short time peaks so that high demands could be carried safely on the turbines.

Assume: 45,000 KW Demand, Energy 20,000,000 KWH per month

This corresponds to 445 hours use of demand or a load factor of 61% and generally speaking is a higher load factor than most steel mills, although this load factor might be obtainable under some conditions.

Cost of generated power = \$73,200 + (.00242 x 20,000,000) = \$121,600.00

Cost of purchased power = \$2,000 + (45,000 x 1.80) + (.003 x 20,000,000) = \$143,000.00

Monthly loss by purchasing power = \$21,400.00

Net return on the Power House investment is:

$$\frac{21{,}400 \times 12}{5{,}000{,}000} = 5.04\%$$

This would not ordinarily be considered an attractive investment for a steel company.

### Non-Coal-Fired Stations

For stations having waste gas available for fuel, a curve similar to Curve No. 1 can be set up; generally speaking, it will be the same curve shown with the fuel cost omitted. For the units shown, we can compute the relative costs for normal operations.

The equation is: \$69,000.00 + .00014E

Monthly Cost—

Of Generated Power = \$69,000 + (.00014 x 15,000,000) = \$71,100.00

Of Purchased Power = \$2,000 + (38,000 x 1.80) + (.003 x 15,000,000) = \$115,400.00)

Monthly loss by purchasing power = \$44,300.00

Net return on investment = $\frac{44{,}300 \times 12}{5{,}000{,}000} = 10.3\%$

These data would indicate that there is small likelihood of securing purchased power at a price to compete with fuel generated from waste heat, for most steel mill installations as this gross return of (12 + 10.3) 22.3% would normally represent the minimum return. This is due to the fact that, of all steel mill loads, the Hot Strip Mill probably has the lowest load factor; and this return would increase materially with an increase in load factor.

The investigation of the comparative cost of purchased vs. generated power does not always show that the correct answer is to purchase all or produce all of the power. It sometimes occurs that the maximum economies can be obtained by purchasing part and producing part of the total requirements.

The following case will illustrate the method of analysis of such a problem:

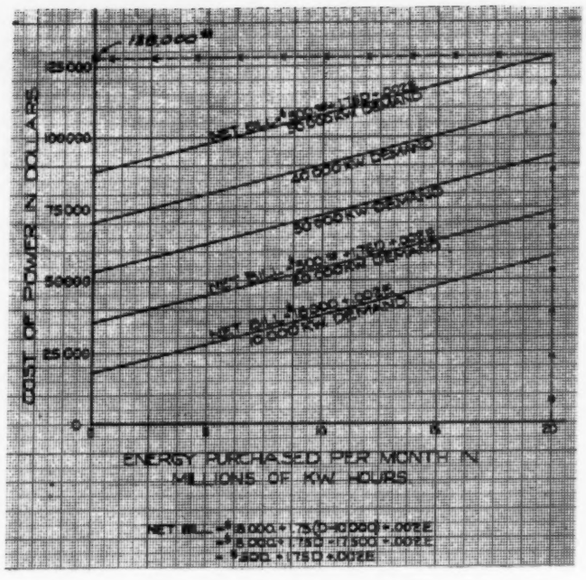



Figure No. 4

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Conditions:

Fifteen minute demand = 45,000 KW

Instantaneous peak = 5,000 KW

Billing Demand = 50,000 KW

Monthly energy consumption, KWH per month = 20,000,000

Case (1)—All power purchased. (Figure No. 4)

Purchased Power Rate:

\$18,000.00 for the first 10,000 KW of demand

\$1.75 per KW of demand above 10,000 KW

.002 per KWH of energy

Monthly Power Bill = \$18,000.00 + (\$1.75 x 40,000) + (20,000,000 x .002) = \$128,000.00

Annual Power Bill = 12 x \$128,000.00 = \$1,536,000.00

Cost per KWH = $\frac{1{,}536{,}000.00}{20{,}000{,}000}$ = \$ .0064

Case (2)—All power generated. (Fig. No. 5)

Assuming that waste heat or by-product fuel is available for 75% of the power production.

Investment required:

| | |
|---|---|
| Cost of two 25,000 KW turbine generators at \$100.00 per KW = | \$5,000,000.00 |

Power Costs:

| | |
|---|---|
| Fixed charges at 1% per month = | \$ 50,000.00 |
| Constant operating cost = ..... | 12,000.00 |
| Incremental operating cost (labor and repairs) 20,000,000 x .00035 = ..... | 7,000.00 |
| Fuel cost on 75% of power = .... | 0.00 |
| Fuel cost on 25% of power = .... | 10,000.00 |
| Total monthly cost of power.... | \$ 79,000.00 |
| Total annual cost of power..... | \$ 948,000.00 |
| Cost per KWH..... | \$.00395 |

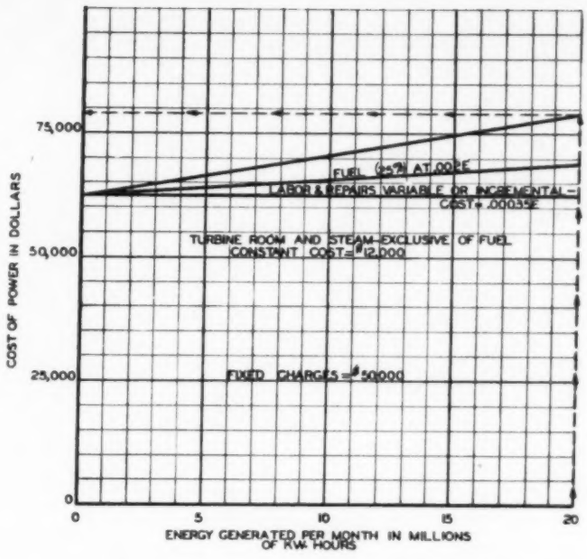


FIGURE No 5 COST OF PRODUCING ELECTRIC ENERGY ON TWO 25,000 K.W. TURBINES

Net return on investment:

$$\text{Case (2) over case (1)} = \frac{\$1,536,000.00 - \$948,000.00}{\$5,000,000.00}$$

$$= \frac{\$588,000.00}{\$5,000,000.00} = 11.76\%$$

If the analysis was stopped at this point, this net return might, in some cases, be considered sufficiently attractive to justify the investment in power producing facilities.

Case (3)—Part generated—Part purchased.

Load division:

12,000 KW fifteen second peaks on generator
22,000 KW base load on generator
16,000 KW base load on purchased power

50,000 KW total demand

Energy:

8,000,000 KWH purchased
12,000,000 KWH generated

Cost of Purchased Power:

$18,000.00 + ($1.75 x 6,000) + (8,000,000 x $ .002) = $34,500.00

Cost of Generated Power:

| | |
|---|---|
| Fixed charges | $ 25,000.00 |
| Constant operating cost | 7,000.00 |
| Incremental operating cost (labor and repairs) 12,000,000 x .00035 | 4,200.00 |
| Fuel cost | 0.00 |
| Cost of generated power = | $ 36,200.00 |

Total cost:

| | |
|---|---|
| Cost of generated power = | $ 36,200.00 |
| Cost of purchased power = | 34,500.00 |
| Total monthly cost of power = | $ 70,700.00 |
| Total annual cost of power = | 848,400.00 |
| Cost per KWH = | .00424 |

Comparison of results:

| | |
|---|---|
| Case (1)—All Power Purchased | |
| Annual power costs = | $1,536,000.00 |
| Investment required = | 0.00 |
| Case (2)—All Power Produced | |
| Annual power costs = | $948,000.00 |
| Investment required = | $5,000,000.00 |
| Net return on investment (two turbines) | 11.76% |
| Case (3)—Part Produced—Part Purchased | |
| Annual power costs = | $848,400.00 |
| Investment required = | $2,500,000.00 |
| Net return on investment (one turbine) = | 27.5% |
| To determine the return on the second turbine generator: | |
| Investment = 25,000 at $100.00 per KW = | $2,500,000.00 |
| Savings on second turbine generator: | |
| With second turbine omitted, using purchased power, the operating cost | $ 848,400.00 |
| With second turbine installed, the operating cost = | $648,000.00 |
| Annual gross saving = | $ 200,400.00 |
| Gross return = $ 200,400.00 / $2,500,000.00 = | 8% |

## SUMMARY

The installation of the first turbine generator shows a net return of 27.5% or a gross return of (12 + 27.5) = 39.5%. The installation of the second turbine generator shows a gross return of 8%.

These data indicate that the installation of only one turbine generator would be recommended, the remainder of the power to be purchased.

The explanation of how such a result is possible may be arrived at by considering that the first turbine generator is in competition with the relatively high cost (on purchased power), low load factor portion of the load; while the second turbine generator is in competition with the relatively low cost, high load factor portion of the load.

The significant point brought out by this analysis is that a comparison limited to whether all the power should be purchased or produced would result in the submission of a recommendation that would not be the most economic procedure.

### Conclusions:

In conclusion, it should be stated that the scope of the subject is too wide to cover completely in the limited space available.

The purpose of the discussion will have been served if the method presented of making comparative cost studies of producing and of purchasing power results in solutions that are made along the lines of sound economics.

It should be emphasized that the true availability of waste heat, carrying charges on investment, and required returns to make an investment attractive are for decision by each company.

# DISCUSSION

PRESENTED BY

GORDON FOX, Vice President, Freyn Engineering Company, Chicago, Ill.

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B. M. JONES, Duquesne Light Company, Pittsburgh, Pa.

A. H. DYCKERHOFF, Dr. Engineer, Commonwealth Edison Company, Chicago, Ill.

*Gordon Fox:* I think the Chicago Section has been honored this evening by having Mr. Bates come on from Pittsburgh and present in such an able and interesting manner a subject which is so timely.

Perhaps (to get a perspective), it will be in order to note what part the steel industry plays in our national power picture. For that purpose, I might cite one or two statistics for the year 1929, as that is the last year of full operations with respect to which statistics are available.

In that year the steel industry is said to have consumed about 9½ billion kilowatt hours of energy. Of that amount, about 3½ billion were purchased and about 6 billion were generated by power plants within the steel plants. So you can see that the steel industry is generating about two-thirds of its power.

Another comparison of interest is to consider that the steel industry consumed about 9½ billion kilowatt hours in a year when all of the utilities in the United States generated something like 95 billion kilowatt hours. In other words, the consumption of the steel industry was equal to about one-tenth of the total utility generation of the country.

Another analysis of some little interest is to compare the total consumption of 9½ billion kilowatt hours with the ingot production of 1929, which was about 56 million tons. That divides out to about 170 kilowatt hours per ton as an average consumption. If we go back into earlier years, we find the ratio of kilowatt hours per ton is considerably lower. Perhaps that is accounted for in part by the fact that there were more steam drives in the earlier years. However, I think it is also to be accounted for partly by the fact that in the earlier years a substantial part of our tonnage was represented by rails, structurals and other heavy products which had a consumption possibly of 100 kilowatt hours from the ore pile to the finished product, whereas at the present time something like 60 per cent of the tonnage is represented by flat products, such as strip, sheet, plates, and the like, and in small merchant products, such as wire rod, all of which represents a consumption of possibly 200 kilowatt hours per ton or more. So there is a decided trend for the industry as a whole to increase its power requirement.

At the same time, there is a trend for by-product fuels, such as coke oven gas and blast furnace gas, to be used in process work rather than as fuel under boilers. So it would seem that the steel industry represents a very large potential field for the utilities to consider.

It might be of interest to say a word about the program of the Soviet Government with reference to electric power for its steel plants. It is hard to generalize, but I might say that most of the steel plants include a power house which is sufficiently large to take care of the turbo-blowers for the blast furnaces and to generate a portion of the total power consumption. However, nearly all of the plants are connected with a high voltage network which will supply a substantial part of the power. In other words, it is a part-generated-part-purchased-power set-up. That practice was dictated partly by the fact that at several of the sites for steel plants over there, there is rather a scarcity of water for plant uses and for condensing purposes. In only one case was it found desirable to install a large regional generating plant right at the steel mill site and to use by-product fuel as part of the fuel for that plant.

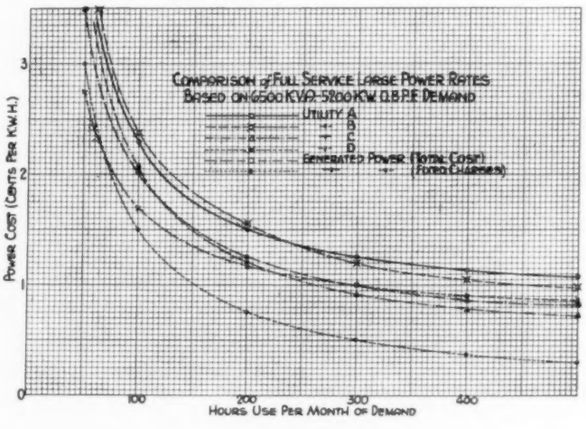



**Fig. 1**

It seems to me that one of the most important conclusions which Mr. Bates reached in his discussion was the fact that it may pay to generate power when the mill is operating at substantially its full production rate, but it is likely to be more economical to purchase power when the mill is operating at a partial rate or when it is substantially shut down.

In order to emphasize that relationship a little more strongly, I refer to Fig. 1.

Mr. Bates has used a graphic method of presenting power costs. Fig. 1 shows a little different graphic method of analysis. Here we have power cost in cents per kilowatt hour in relation to the hours' use per month of the demand. These curves are prepared with reference to a relatively small load, a much smaller

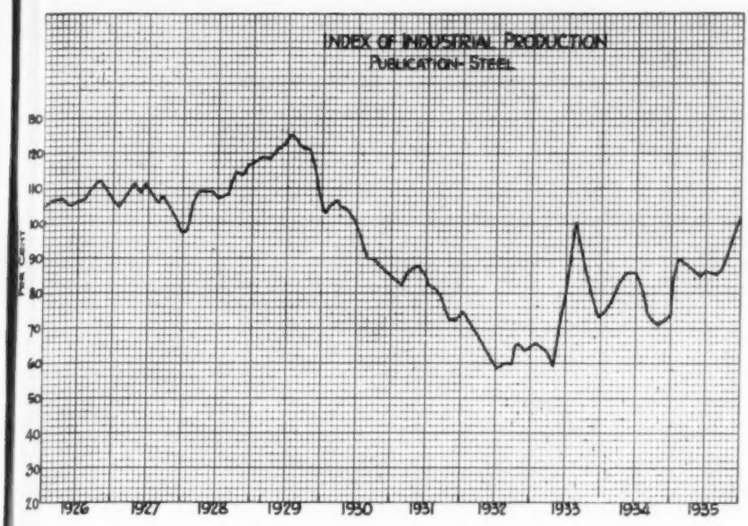



Fig. 2

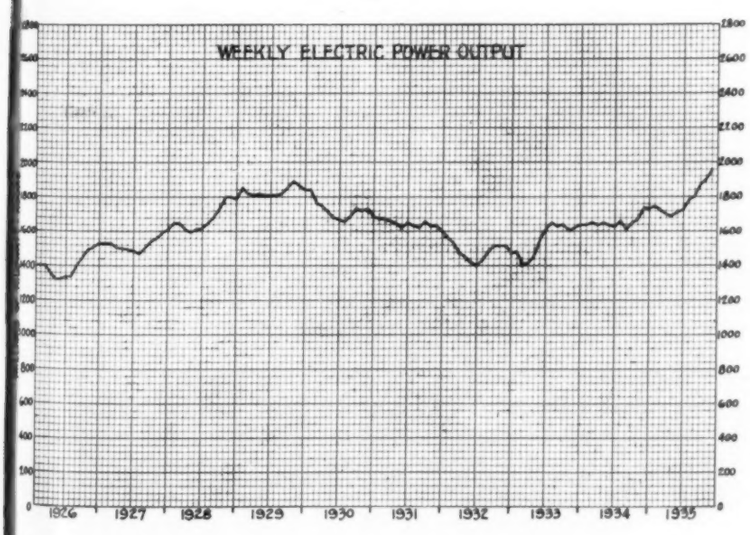
load than Mr. Bates has been discussing. However, the general principles are more or less the same.

If a plant used its demand constantly during approximately 720 hours a month, it would be realizing the fullest possible use of its demand. Of course that is impossible. If a plant operation has a load factor on the order of 40 per cent, it will realize about 280 hours' use of its demand.

The cost of purchased power is represented by several curves in Fig. 1, as indicated by the legend. Four different curves are shown referring to rate schedules of large utilities supplying industrials in this general section of the country. There is quite a little variation between the rates represented by these curves, but you will see all of the curves are of the same general shape.

Fig. 1 also includes a curve plotted to show the cost of generated power. The cost of generated power is based on more or less empirical figures. I have used

Fig. 3




$100 per installed kilowatt, the same as Mr. Bates used. I have assumed that at the time of maximum demand there would be a reserve, either running or standing, of 20 per cent. I have, further, used a fixed charge figure of 15 per cent, which might be made up of 6 per cent interest, 1.5 per cent taxes and 7.5 per cent depreciation. I would call your attention to the fact that if you put into a fund each year $7.50 for each $100 of plant investment, and allow it to accumulate with interest at six per cent, you will accumulate the entire first cost of your installation in ten years. In other words, an allowance of 7½ per cent for depreciation will return your investment in ten years. The figure which Mr. Bates used, of 5 per cent, on the same basis will retire your investment in about fourteen years.

On that basis we arrive at a curve representing cost of generated power which is intermediate between these upper two curves and the lower two curves showing cost of purchased power, but which coincide quite closely with them. In other words, we arrive at a generated power cost which compares generally with the cost of power purchased from utilities. In fact, we may be led to suspect that the public utilities have plotted out the costs of generated power in some such manner and have determined just about what the traffic will bear and have arranged their rates accordingly.

I would particularly call your attention, however, to the lower curve shown in Fig. 1. This lower curve represents that part which fixed charges play in the total cost of generated power. The upper curve showing total cost of generated power is just five mills per kilowatt hour higher than the lower curve showing fixed charges. In other words, the difference between the two curves is a fixed quantity of five mills per kilowatt hour, which is assumed in this case as the operating cost; that is, the cost of fuel, maintenance, attendance, and the like. Here, you will notice that if you only have 100 hours use of the demand, power costs about 1.5 cents per kilowatt hour before you put a pound of coal under the boiler. If you have 200 hours' use of demand, the fixed charges are about three-quarters of a cent per kilowatt hour before you start to generate any power. In other words, unless you have a large use of your demand, the fixed charges associated with the investment in generating plant is a substantially larger factor than the operating cost of generating the power.

I think we sometimes lose sight of the importance of fixed charges in the cost of generating power. Bear in mind that this comparison refers to the case where the consuming plant is operating substantially at capacity, and is developing a demand which loads the generating equipment to approximately 80 per cent of capacity. If you will consider what happens when operations are only partial and when the actual demand is about half as much as we have assumed from this curve, then you will see that the curve representing fixed charges will move up. Fixed charges will be twice as great with respect to that reduced demand. Therefore, operations on partial load are likely to be relatively expensive when you are tied down to an investment in generating plant, the fixed charges of which go on every month regardless of the number of tons or units of product you may be producing.

Purchased power and generated power have the same general shape of curve with reference to hours' use of demand, but with reference to the fixed charges, or the demand charge which corresponds to the fixed charge element of the generated power, there may be a substantial difference between purchased power and generated power. If we put in a power plant, we have the investment; the fixed charges are there every month. But in the case of purchased power, perhaps we will have a high demand charge and perhaps not. That depends on the character of the demand feature in the rate, and particularly whether it is a monthly demand or an annual demand. In the case of a monthly demand rate or a rate which takes into consideration demand variations from month to month, there is an opportunity for a substantial saving due to the fact that we are not bearing so much in fixed charges during the months that we have partial operation. That may be of considerable importance when you consider the cost of the product. If you have a generating plant, the fixed charges go on just the same. When you make half as many tons of product on which you have to unload those fixed charges, the cost per unit of product therefore is more at a time when the tonnage is less. In depression times the cost of power may relatively go up. If you are purchasing power and do get a benefit due to decreased demand, at the very time when you are most anxious to get this benefit, namely, when the production is low and competition is keen, there may be a substantial saving due to the sharing of fixed charges.

It does seem to me that one of the big things that utilities might offer is not so much a matter of energy in kilowatt hours as it is a readiness to serve the industrial without the necessity of putting in a big investment which cannot in any way be unloaded during hard times. Utilities may be in position to do this because of the effect of diversity in demands and the requirements of different classes of load. A comparison of curves showing variations in industrial production and in electric power produced by the utilities, shown in Fig. 2 and 3, indicates to what a large extent the utilities, shown in Fig. 2 and 3, indicates to what a large extent the utilities were able, during the depression years, to utilize their generating capacity and to fill up, with other load, the valley in power consumption resulting from decreased industrial operations.

*G. W. Ousler:* Mr. Bates has given a very excellent presentation on the subject of private plant versus public utility power for steel mill operation, and has referred, particularly, to the use of power for the new strip mills which are being installed in quite a few sections of the country. It is quite interesting to note that, at the present time, the large steel companies are giving a great deal more consideration to the purchase of utility service than in the past, leaving the reaction that the steel companies have come to the conclusion that they should concentrate all of their activities and efforts on the production of steel and leave the generation of power up to the industry whose sole business is the production of electricity. This seems very logical because, from the large utility systems, which are now in operation in most parts of the country, customers generally should be able to purchase electricity at an economic advantage to themselves and thus be relieved of the necessity of investing money in power plants and operating such plants when this money and effort could be used more profitably if confined entirely to the manufacture of steel.

I think it should be emphasized at the outset that it is unwise for a utility to attempt to sell large blocks of power for strip mill operation or, in fact any kind of steel mill operation, unless both the customer and the utility profit from such a transaction. Unless the negotiation is based on this premise the future position may become extremely unstable and sooner or later service will be discontinued, probably at a loss to both parties. As a utility man, therefore, I feel that it is unwise for both parties to enter into an agreement for the sale and purchase of utility service unless the steel company and the utility are convinced from the outset that there is something to be gained by both parties to such a contract. These loads are too large, the investments are too big for either party to coerce the other into a contract which is not economically justifiable.

On the other hand it is our opinion that, in a great many cases, the utility company can sell large blocks of load to the strip mills at a profit to themselves and a saving to the steel company. At the present time, we are negotiating with the Carnegie-Illinois Steel Co. in Pittsburgh for a load which may be in the neighborhood of 15,000 to 30,000 kilowatts. We are approaching this negotiation entirely from the point of view of mutual advantage to both parties and are working closely together so that conclusions can be reached from a cooperative study rather than from the point of view of trading or jockeying for position. I recommend this method of negotiation if at all possible.

Of course, we may not be able to successfully negotiate a contract with the Steel Corporation, but if such is the case we believe that a decision for a private plant will be based on some sound principles. As I said before, however, we believe that we can get together with the Corporation on the sale of firm power.

Obviously the utility company must charge a rate which will allow, after deducting operating expenses, an adequate return on the investment which it is necessary to allocate to this business. This rate must also be prepared so that it is non-discriminatory and will allow its application to any customer who can meet its terms and conditions.

For the benefit of those here and, particularly, the utility men, it might be interesting to point out some of the features which must be studied very carefully in arriving at a price for which blocks of power of this size can be sold.

First of all the capacity which the utility company must provide for a strip mill load needs very careful consideration. Mr. Bates has pointed out the load cycle which a strip mill imposes on a power system. It is readily seen that the load is of a very fluctuating nature and that, during a fifteen minute period, the peaks may be two to three times the size of the base load; and that these peaks occur frequently during a fifteen minute interval. Obviously, any fifteen minute integrating demand meter will show a demand of a

value between the base load and the top of the peaks. For example, if the base load is 20,000 kilowatts and the peaks 50,000 kilowatts, a fifteen minute demand meter will probably show a demand between 25,000 and 35,000 kilowatts. However, since the peaks occur frequently, the generating capacity, which would have to be supplied to carry this type of load, would probably have to be somewhere between 40,000 and 50,000 kilowatts, particularly on the steam end. Therefore, the utility must base its charges for generating capacity on an amount between 40,000 and 50,000 kilowatts rather than for a load between 25,000 and 35,000 kilowatts as shown by a fifteen minute demand meter. This question has been studied very carefully by our engineers and operating men and we have come to the conclusion that the fluctuating loads must be measured in order to determine a fair value for the capacity which must be set aside to serve this type of load, and that this capacity can not be determined by the demand measured by an intergrating demand meter. This is one of the features which must be given serious consideration in order that the utility may be fully compensated for the capacity which it must provide to serve the loads which are caused by strip mill operation.

The utility has no desire to charge for capacity that it does not have to provide to serve a certain load. Therefore, if the nature of a load is such that a fluctuating peak occurs only very infrequently it might be ignored as it probably would have no effect on capacity. However, where it is known that peaks, lasting from 20 to 30 seconds, of a size two to three times the base load and having an occurrence of every minute or two then it is obvious that the utility must provide capacity to carry these peaks and charges for service will, therefore, have to be based on the cost of this capacity. This is well emphasized by Mr. Bates when he indicates in his paper that if a private plant was installed, generating capacity of 50,000 kilowatts would be needed to carry the load as shown on his Curve No. 2, which he indicates would have peaks of around 58,000 kilowatts.

It is necessary that the utility protects its investment by demanding a rather long term contract because, in a great many cases, the size of the load of a strip mill is a fair percentage of the peak load of a company and, in many cases, may be several times the size of any of its regular customers. If this is true then the loss of such load would leave the utility in a position where it might not be able to sell this excess capacity to other customers for many years to come and would thus lose a rather large amount of money each year represented by the fixed charges on this extra investment. Relatively long term contracts, therefore, seem essential.

The utility must further protect itself by the inclusion, in its tariff, of a coal clause to vary the price of energy with the cost of coal; it should also include tax clauses which should provide for an increase in rates if increased taxes are to be borne by the utility and possibly even labor clauses which would vary the price of energy with a marked change in the cost of labor.

The steel company should be very careful to examine its costs from every angle. For example, the ability of a steel company to use by-product gas as a fuel, gives it an opportunity to generate electricity in a very economical manner. I think it is generally true that a public utility has a very difficult time competing for a large block of load if the steel company has an abundance of by-product fuel. On the other hand the steel company must be certain that its operations are such that they have by-product fuel when they have need for electricity before they arrive at the conclusion that they do not need to burn coal as a fuel. This is sometimes a situation which is overlooked in an economic study. Therefore, the Steel Corporation, which is making a study of power requirements, must be sure that their production of by-product gas can be synchronized with the generation of electric power.

The steel customer must also be very certain as to the investment which it must make in power producing equipment. It must be sure to include the cost of all equipment, such as buildings, structures, water tunnels, coal handling equipment, boilers, generators, including spare capacity, etc., so that the final estimate covers all necessary equipment. This may seem to be a very obvious statement. We have found that, in some of our negotiations, not so much with the large companies as with the small companies, some of these items are left out of the total cost and the picture, therefore, becomes distorted. Furthermore, adequate operating expenses must be applied to the operation of the new power plant and these costs not submerged in other steel mill operations if a proper analysis is to be made.

I also believe that, if the result of a study shows savings in favor of private plant operation as compared to purchased service that unless these savings represent a good return on the investment to be made, a customer would find it much more profitable to invest the money in steel producing equipment rather than in power producing equipment. By the word "savings" I mean the balance of money which remains by subtracting from the purchased power cost the operating expenses of a private plant and the fixed charges on the investment which has to be made in this private plant.

I have tried to point out some of the features which must be given serious consideration in carrying on a negotiation for the sale or purchase of large blocks of power for strip mill operations and I believe that they are in accordance with the fundamental ideas expressed by Mr. Bates. I would like to repeat and emphasize again that, unless the results of a negotiation show a mutual advantage to both parties, the proposition probably is not sound and will eventually fall of its own weight. I would like to point out again that if it is at all possible these negotiations, involving such large blocks of power and such heavy investments, should be carried on in a cooperative manner to determine jointly whether or not the utility can sell power to the advantage of the purchaser and to itself. These analyses will vary in different locations due to a different set of circumstances, but it should not be difficult to determine from any given set of circumstances if a large strip mill should install its own power plant or should purchase its power from a local utility.

*H. A. P. Langstaff:* The paper is an excellent treatise on the subject under discussion. Mr. Bates has shown that practically every installation is in many ways special and requires individual detailed study and he is to be complimented on his broad and fair treatment of the problem. It is evident that many of the most modern features of design have been embodied in his selection of electrical equipment. Many central station customers, both large and small are now being supplied with uninterrupted service made possible by available high speed and fully automatic electrical features, full advantage of which may be taken in those cases especially where continuous production warrants.

The 132 KV switching arrangement very closely simulates the switching arrangement used for many years by the West Penn Power Company which has proven to be quite economical, flexible and safe, with continuous service as the resultant goal.

He is to be complimented on the simplicity of the 132 KV and 6600 volt switching facilities. Throughout a period of years operation will prove this arrangement to be well justified. The use of high speed switchgear and the coordination of motor design and controls indicates a full consideration from a continuous production point of view. To many industrial installations whose power is supplied by central stations, by their own generating plants, and by parallel operated combinations of the two,—upon all of which so-called voltage dips occur—consideration has been given to proper relay application to the end that the needs of continuous production may be met. Newly developed switchgear equipment provides still more possibilities for such an accomplishment.

Mr. Bates makes no mention of immediate reclosing facilities which if properly applied presents a method in many cases of increasing the possibilities of continuous service; it may be that the station capacity is such that immediate reclosing is not an economical requisite.

I am of the opinion that high speed excitation may be the proper answer to the problem of voltage regulation during non-rolling intervals. Future operation will, no doubt, prove very good judgment has been used in the segregation of the 600 volt buses. Complete isolation and insulation of 600 volt buses has proven advisable for continuous production.

The use of high speed recording meters especially during the first year's operation when such a large installation is in a more or less experimental stage often furnishes a means of obtaining charts valuable for operational study purposes.

Again let me state that Mr. Bates has in his paper given in most excellent form an exposition of the many factors which must be considered when such an important matter as the power supply to a large mill is to be decided.

*B. M. Jones:* I don't want to seem to be stuffing the ballot box, for I am the second one from the Duquesne Light Company. I am not in the sales department, and am just an engineer, so if Mr. Bates wants to talk our sales department into giving him the power, it is their funeral and not mine.

We have studied similar rolling mill loads, and believe that if you mill people pay careful attention to the diversity of your load so as to prevent all of your mills encountering heavy rolling at the same time, you can save a considerable amount of money in your billing demand, for in some cases the peak demand created represents a considerable portion of the bill.

In our studies of these rolling mill cycles, we have found that as much as 20 or 30% reduction in the peak KW demand created can be obtained if you can control the flow of billets to the various mills. That is, hold up kicking the billets out of the heating furnace on one mill for a short while, a matter of 20, 30 or 40 seconds, until another mill is empty.

Mr. Bates pointed out that if the billing demand for the large peaks is a large portion of your total billing demand, the 20 or 30% saving on the peak will amount to a considerable sum of money.

He also said that by spending a relatively small sum of money for control equipment, viz. governor control, and signaling and anticipating devices, your own generators could probably pick up a considerable portion of this peak and the power company would not get such a great portion of it. This, of course, applies when the Steel Company's generators operate in parallel with the power company.

We have load charts for five or six large rolling mills, some of them covering parallel operation with the utility's and Steel Company's generators, and others where the power company carries all of the steel company's electric load. On one chart, there is an abrupt change—from 6000-8000 KW to 20,000-22,000 KW—in the input to the steel plant. In this case the steel company and the power company operate their generators in parallel, and it was suspected that something had gone wrong with the governor control on the steel company's generators. This condition was corrected and the swing came back to the 6000-8000 KW.

Generally, these control devices cost a relatively small sum of money in comparison with the electrical investment necessary for parallel operation. The modern governor control is available to cause the steel company generators to pick up the load so that the power company system does not get the very severe surges, and many power companies have been using such governor controls for a long time and not necessarily for this purpose, but for other reasons.

We feel sure that if you make careful study of this matter, you can cut down the peaks which the power company will pick up where there is parallel operation.

*A. H. Dyckerhoff:* It is not only befitting but a great pleasure to me to compliment Mr. J. W. Bates on his paper and the fair presentation of this—always controversial subject. On the basis of the load condition, data and calculations given, he shows when the purchase of the entire amount of electric power is warranted, also when part of power should be purchased and when the purchase of power is not advisable, with the value of the by-product fuel omitted. (See subject seven.)

There are several principles emphasized by him in which I am in complete accord. These are:

The careful establishing of costs of purchased and generated power.

An analysis of such costs on parallel lines and under identical conditions.

The elimination, as far as possible, of fixed amounts of money payable each month over which the purchaser has no control.

If these principles are strictly applied to the case under discussion, we will find that several comments and additions are in order, all of which will swing the conclusion arrived at by Mr. Bates still more towards the purchase of power. Here the writer should like to bring out the following salient points:

*First:* Coal basis and rate used for comparison.

The cost of power generated in a steel plant has been based by Mr. Bates apparently on $3.00 per ton (2000 lbs.) of coal having 13,000 btu per lb. representing evidently Pittsburgh conditions. This is equivalent to 1.154¢ per therm. The utility rate on the other hand, used in comparing generated with purchased power, appears to be one available for large contracts in the vicinity of Chicago, Illinois, where the cost of coal is in the neighborhood of about 1.66¢ per therm, or about 44% higher than in Pittsburgh. Even if allowance is made for a better performance of the turbine generating unit than he assumes, and if the correct respective fuel cost is applied, it must be conceded that the showing of purchased power will improve.

*Second:* Short time peaks and their importance.

Mr. Bates' paper gives 58,500 kw as short time peaks of the load serving as basis, which he proposes to carry by a capacity of 50,000 kw in two units. Since these short time peaks apparently recur quite *regularly*, it is doubtful and very much an open question if two 25,000 kw maximum rated standard turbine units will suffice to carry the load. The discussions the writer had with representatives of manufacturers of turbines brought out the fact that very occasional short time peaks of 10% to 15% in excess of the maximum continuous rating are permissible, but not frequently recurring momentary demands. Therefore, the selection of two 25,000 kw standard rated units barely gives sufficient margin in capacity; reliability of service calls for 2—30,000 kw units requiring a higher investment; this capacity does not include any standby. (See subject four.) Such conditions under which a somewhat larger capacity must be selected bring out forcefully the advantage of electric power purchased at certain rates having a considerable period of time, for instance, one-half hour, as basis for the determination of the maximum demand, at which rates the industrial pays only for the actual load.

This leads us to the question:

What short time or momentary demands of electric power when purchased from a utility are admissible and reasonable?

They are, of course, dependent on the size of the utility system, and somewhat on several other conditions prevailing at the locality serving the particular load. Here the writer should like to mention load conditions relating to several industrials purchasing the power in the same locality.

Plant A—

| | |
|---|---|
| Monthly average load about | 41 kw |
| Maximum ½ hour demand about | 240 kw |
| Instantaneous maximum demand | 1200 kw |
| Ratio of ½ hour demand to average load | 6 to 1 |
| Ratio of instantaneous demand to average load about | 30 to 1 |
| Ratio of instantaneous demand to ½ hour demand | 5 to 1 |

Plant B—

| | |
|---|---|
| Monthly average load about | 1431 kw |
| Maximum ½ hour demand | 1792 kw |
| Instantaneous maximum demand about | 1794 kw |
| Ratio of ½ hour demand to average load | 1.24 to 1 |
| Ratio of instantaneous demand to average load | 1.25 to 1 |
| Ratio of instantaneous demand to ½ hour demand, practically | 1 to 1 |

Plant C—

| | |
|---|---|
| Monthly average load about | 3788 kw |
| Maximum ½ hour demand about | 7100 kw |
| Instantaneous maximum demand about | 11200 kw |
| Ratio of ½ hour demand to average load about | 1.87 to 1 |
| Ratio of instantaneous demand to average load | 2.96 to 1 |
| Ratio of instantaneous demand to ½ hour demand | 1.57 to 1 |

When comparing, for argument's sake, Plant A with Plant C, it must be conceded that the utility would be discriminating if it would allow the same rate to Plant A as to Plant C, having a ratio of the instantaneous to ½ hour demand less than one-third of that of Plant A. Under ordinary conditions, Plant C has a ratio of about 1.40 to 1, which must be considered reasonable and permissible when the power is supplied by a large system.

Mr. Bates carries out one calculation and set-up which shows that it is advantageous under certain conditions to purchase a part of the load. It should be made clear here that a division of load according to a certain ratio should also imply a definite ratio or division of momentary loads between generated and purchased power. This is not always readily feasible due to the close regulation of utility systems; but if this is not feasible and the utility system carries a larger share of instantaneous demands, it should be

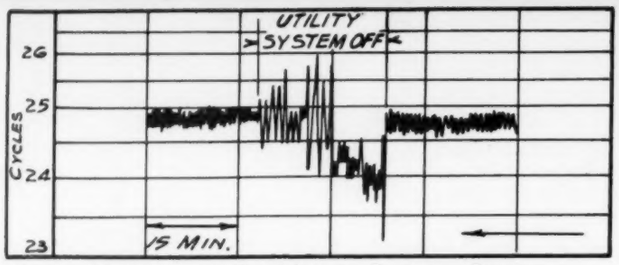



FIG. 1 FREQUENCY OF MIXED POWER PLANT

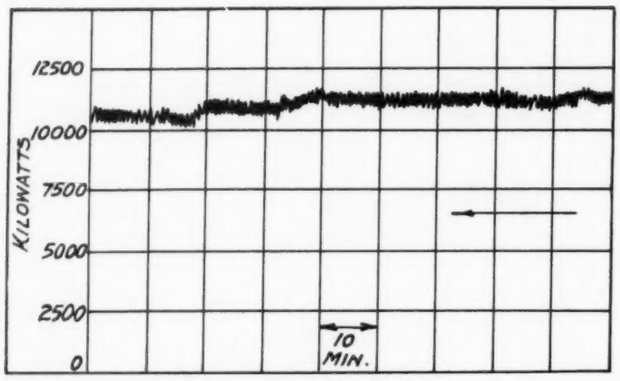



FIG. 2 LOAD TO BE SERVED

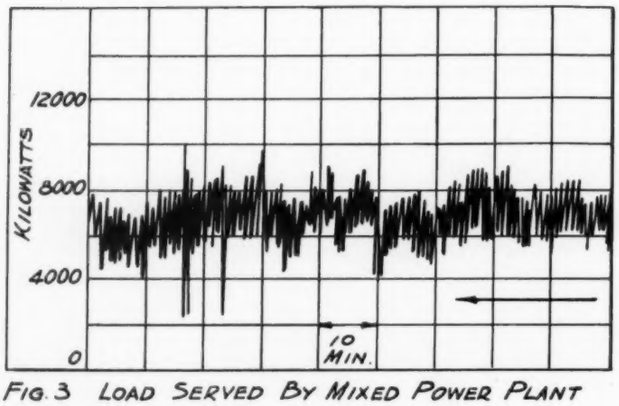



FIG. 3 LOAD SERVED BY MIXED POWER PLANT

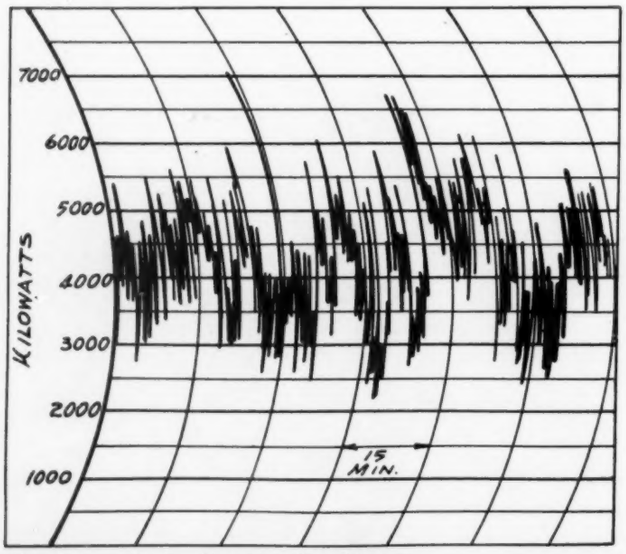



FIG. 4 LOAD SERVED BY UTILITY

given due credit in the *computation of actual costs on a parallel and identical basis.* It is assumed here, as in the paper by him, that turbine type units of the steel mill power plant would carry part of the load.

The conditions, however, become much more aggravated if the steel mill power plant is of a mixed type, i.e., if it consists of steam turbine and gas engine units and the frequency varies considerably. If, now, such a power system is to furnish electric energy to an additional mill as he describes, and a large utility system with close frequency regulation is to be connected to such a system for the purpose of sharing the load of the additional mill, having short time demands, the utility service is entitled beyond the shadow of doubt to a still greater credit, depending on the very high and frequent momentary demands and on the degree of frequency stabilization which the utility system effects. As proof, it will suffice to give here four diagrams. Figure 1 shows the stabilizing effect of the utility system on the frequency of the steel mill system. Figure 2 gives the load which is of very mild character, varying not more than 10% in excess of the mean value, which load was fed by two sources, one being a mixed type steel mill power plant and the other a utility system. The part of that load carried by the mixed steel mill power plant is shown in figure 3 and the share of the load supplied by the utility in figure 4. The variable energy demands of other parts of the mill system and the insufficient regulation of gas engine units, produced additional stresses and energy demands. The energy delivery by the mixed type steel mill power plant varied from a mean value by 63% (figure 3) and the energy delivery by the utility system by about 90% (fig. 4). The result of such violent energy demands is the stabilization of the mill power system as is plain from figure 1.

*Third:* Actual long range performance of steel mill turbine generating units and actual long range cost of purchased power.

Too frequently the computed cost of generated electric power omits the energy required by the auxiliaries (gross and net cost) or is based on a definite constant steam pressure and a certain vacuum. It is well known that these latter premises do not hold generally under steel mill conditions and that therefore the operating efficiency is less than anticipated and usually decreasing as time goes on with attendant increase in cost. This is in contrast with the cost of purchased power, definitely metered as net, the trend of which has been generally downward. In addition the average cost of purchased power is usually lower than the computed anticipated cost, (See Subject Six).

*Fourth:* Stand-by.

As far as the writer can discover Mr. Bates has made no provision for a debit against plant generated power for stand-by. The writer construes one sentence of the paper that Mr. Bates would use an existing generating unit as a spare. This, however, does not place the "comparison on parallel lines and identical conditions." which comparison calls for a provision of a certain stand-by capacity of the steel mill power plant with attendant additional fixed charges. For a separate load having momentary peaks of 58,500 kw, a capacity

of either 50,000 or 60,000 kw must be chosen with a stand-by capacity of 20,000 or 25,000 kw, depending on the rating of individual units; however, if this load is a part of a larger mill system, a definite stand-by capacity must be assigned to this particular load, depending somewhat on local conditions. It certainly cannot be less than 12 to 15% of the additional capacity, or about 6000 to 7500 kw. The resultant fixed charges of this stand-by capacity should be added to the total cost of generated power if the comparison is to be on a par with purchased power. The rate of utility power provides for a reserve in generating capacity and also usually makes a provision of sufficient line capacity to carry the load in case of breakdown of one line.

*Fifth:* Cost of purchased power at shutdowns.

Here the writer should like to refer to the hypothetical case, which Mr. Bates emphasizes, in which case the minimum monthly bill would be $62,500 for a normal demand of 38,000 kw and one peak of 50,000 kw, at a minimum charge of $1.25 per kw of demand holding for eleven months. In case of a shutdown for three months the sum of 3 x $62,500 or $187,500 for power not received would have to be paid, according to Mr. Bates. But how about the fixed charge of a steel mill power plant which would go on regardless for the same number of months?

*Personally*, the writer feels that the rates on the monthly basis are more suitable for steel plants as long as the iron and steel industry is subjected to such variable rates of operation as in the past. The purchaser has also under his control the amount of power drawn and thereby the money payable each month. (See subject six.)

*Sixth:* Investment, fixed charges and average demand charges.

Mr. Bates states that $100.00 per kw of installed capacity is well accepted by steel mill and public utility engineers. Referring to the latter, I doubt very much if this is the case. While the figure of $100.00 is applicable for very large power plants, statistics show that medium capacity plants require an outlay of between $110.00 and $115.00 if the operating costs, including maintenance, are to be and to remain low, such as is used by him. In spite of certain changes which have occurred in the last six to eight years, involving the contradictory trends of higher cost of some equipment and the lower cost of other material, a fair figure for a medium output and well built plant remains about $110.00 to $115.00 per kw.

In regard to the fixed charges of 12% used in the paper, they are in the writer's experience likewise too low, in spite of the low money rates prevailing at present. It is his understanding that industrials for several reasons are still applying fixed charges of 14% to 15% for projects pending as before. Interest during the construction period is not paid by the steel plant in case of purchased power.

While the fixed charges of a private power plant go on and the rates are definite until reduced, experience shows that the average actual demand is lower by 7.5% to 10%, than the maximum demand of the year, so that the average or actual demand charges when purchasing power are also lower. One steel plant in the Chicago district showed 8.6% in 1934 and 9.1% in 1935. Therefore, on this score, when figuring *actual* average cost of purchased power an allowance of 5% in the demand and thereby its charge is deemed conservative.

*Seventh:* Value of wasteheat and of by-product fuel.

Under the heading "Non-fired coal stations," Mr. Bates omits the fuel cost for stations having waste gas available for fuel. This procedure is in principle decidedly restricted. The conception that fuels and wasteheat which are available as by-products in steel plants do not "cost" anything, has been given up since the war. If blast furnace and coke oven gas were not available within a steel plant corresponding amounts of other fuels would have to be purchased. Therefore, these gases, as well as wasteheat in any form, have a definite fuel value as long as the demand for energy is equal to or exceeds the supply of energy within the plant. However, if there is a surplus of energy, that surplus represents only such a value as may be obtained through its sale.

It would lead here too far to discuss the fuel valuation which depends largely on the conditions of each individual plant; it suffices here to say that the omission of the fuel component when computing the cost of steel plant generated power is warranted in relatively few instances. Therefore, the conclusion arrived at by Mr. Bates as applying to plants having waste gas available for fuel is greatly limited.

Conclusion:

Applying the foregoing comments and points raised properly to Mr. Bates' paper, it can readily be computed and seen that sound economics demand the purchase of power—either total or partial—as well as the cooperation with the utilities in many instances, to say the least.

The arguments offered here are not intended as criticism, but to strengthen the conclusion to which Mr. Bates himself arrives. The writer has the good fortune of having been on "both sides of the fence", so to speak, in working on power and fuel problems for a large steel corporation for ten years, and also on the coordination of energy structures of steel plants and utilities for a group of utilities for a longer time. In his view, therefore, he feels that both steel and utility interests should meet with perfect frankness and without prejudice.


***ATTEND THE***

**CONVENTION**

**AND**

**EXPOSITION**

**SEPT. 22 - 23 - 24 - 25, 1936**

**DETROIT, MICH.**

# *T. E. Millsop*

## ELECTED PRESIDENT OF WEIRTON STEEL COMPANY

T. E. MILLSOP

▲ T. E. MILLSOP was elected president of the Weirton Steel Company at a meeting of the board of directors June 25, to succeed the late John C. Williams, who died last month, it was announced by Ernest T. Weir, Chairman of the Board of the Weirton Steel Company and of its parent organization, the National Steel Corporation.

At 37 years, Mr. Millsop is probably the youngest high executive in the steel industry. He has been connected with the Weirton Steel Company in various capacities since 1926, and for the past year, as executive vice president, has been the acting head of the firm.

Except for an interruption of three years during the World War, when he served as a combat pilot with the Canadian and American armies, Mr. Millsop's entire career has been spent in the steel industry. Typical of many steel leaders, he has held a variety of jobs, ranging from his start as an open hearth laborer to his present position.

Born in Sharon, Pa., on December 4, 1898, the son of George and Mary Millsop, he received his education in the public schools of his native town. In 1913, at the age of 15 years, he went to work in the open hearth department of the Carnegie Steel Company plant at Sharon. During the next three years, he held open hearth jobs in steel plants at Sharon, Farrell, Pa., Ensley, Ala., and Butler, Pa.

As soon as he reached enlistment age, he left Butler and went to Montreal, Canada, where a few days after his eighteenth birthday in December, 1916, he joined the Canadian Air Service as a student flyer. Within a few weeks his training was completed, and he was sent overseas. He served with the Royal Flying Corps until the United States entered the War at which time he was transferred to the American Flying Service. His advancement with the United States Army was rapid and in March 1919, after more than two years of active service, he was discharged with the rank of captain.

For the next six months, he "barnstormed" the country as a stunt flyer, after which he returned to the steel industry, entering the blast furnace department of the Youngstown Sheet and Tube Company. A few months later, in 1920, he returned to Sharon where he got a job driving rivets with the Standard Tank Car Company. Within a short time, he was made foreman of the plate department. In succession, he was promoted to assistant superintendent of this department, then director of purchases, and finally, production manager.

He resigned from the latter position in 1925 to enter the scrap business with the Rotter-Speer Company, of Cleveland, O., where he remained for a year. From Cleveland, he went with the Weirton Steel Company, beginning as a salesman in December, 1926.

He became assistant sales manager in January 1929, and on May 1, 1931 was appointed assistant to the president, from which time his work was in the administrative end of the business under the direct supervision of Mr. Williams. Mr. Millsop was elected vice president on January 1, 1934, and in July 1935, when illness made it necessary for Mr. Williams to lessen his business activity, Mr. Millsop was made executive vice president.

# MAINTENANCE OF LUBRICATING OILS

## MODERN METHODS AND TREATING SYSTEMS

By R. P. DUNMIRE, Vice President
The Buckeye Laboratories, Inc.
Affiliated with The Alliance Machine Company
ALLIANCE, OHIO

**Paper presented before the Association of Iron & Steel Electrical Engineers**

▲ IT IS AN admitted fact that industrial organizations and utilities will spend exceedingly large sums of money for turbines, reduction gears, large rolling mills and other heavy duty equipment, and overlook the expenditure of a very small percentage of the net investment for maintaining and keeping the most essential portion of this equipment in the best condition possible. Unless the lubricating oil for such equipment is kept in the best possible condition, shut-downs of such equipment will result, and enormous expense for repairs, loss of production and the loss of large quantities of lubricating oil will result.

In ordinary boiler operation industrial organizations go to great expense for water purification systems for maintaining the highest possible quality of water in a boiler, so as to prevent deterioration of the boiler and other equipment, but hesitate spending sufficient money to protect equipment which costs many times more and is more dependent for its operation on a single factor; viz., the lubricant.

It should be pointed out that to accomplish the best maintenance possible on lubricating oils that the initial investment is going to be slightly greater than for less adequate equipment but the lessening of hazard to operation is really of an insurance nature and the total cost represents only a very small portion of the original investment in major equipment which is definitely dependent on the lubricant for its operation. In a great many cases the loss of production of a single shut-down together with repairs to equipment and the loss of the oil which caused the damage, is in excess of the total cost of adequate equipment for maintaining the oil in the best condition possible.

R. P. DUNMIRE

### LUBRICATION COSTS

#### Hidden Lubrication Costs

1. PRODUCTION LOSSES. Plant output lost while equipment is shut down for cleaning or changing lubricants. (Even where production conditions are such that special shut-downs for lubrication have heretofore been avoided, there is more certainty of avoiding such shut-downs when more durable oils are used. This greater insurance against production losses has a monetary value.) $.....?

2. OVERHEAD LOSSES. Interest, depreciation, supervisory and office expense on all equipment for lost time due to shut-downs on account of lubrication. (The insurance value of greater protection against these losses must be considered as in item 1. $.....?

3. MATERIAL LOSSES. Gaskets, packing, rags and kerosene required in cleaning lubricating system and changing lubricants $.....?

4. INTEREST AND DEPRECIATION LOSSES. Loss on extra servicing and reclaiming equipment. $.....?

5. MAINTENANCE LOSSES. Labor required for cleaning or changing lubricants. (Even where the labor force cannot be reduced because of other work, there is a distinct saving resulting from the greater time the engineer or his assistant has available for more important duties when the more durable oil is used.) $.....?

6. FRICTION LOSSES. Additional fuel purchased because of power lost in bearings. $.....?

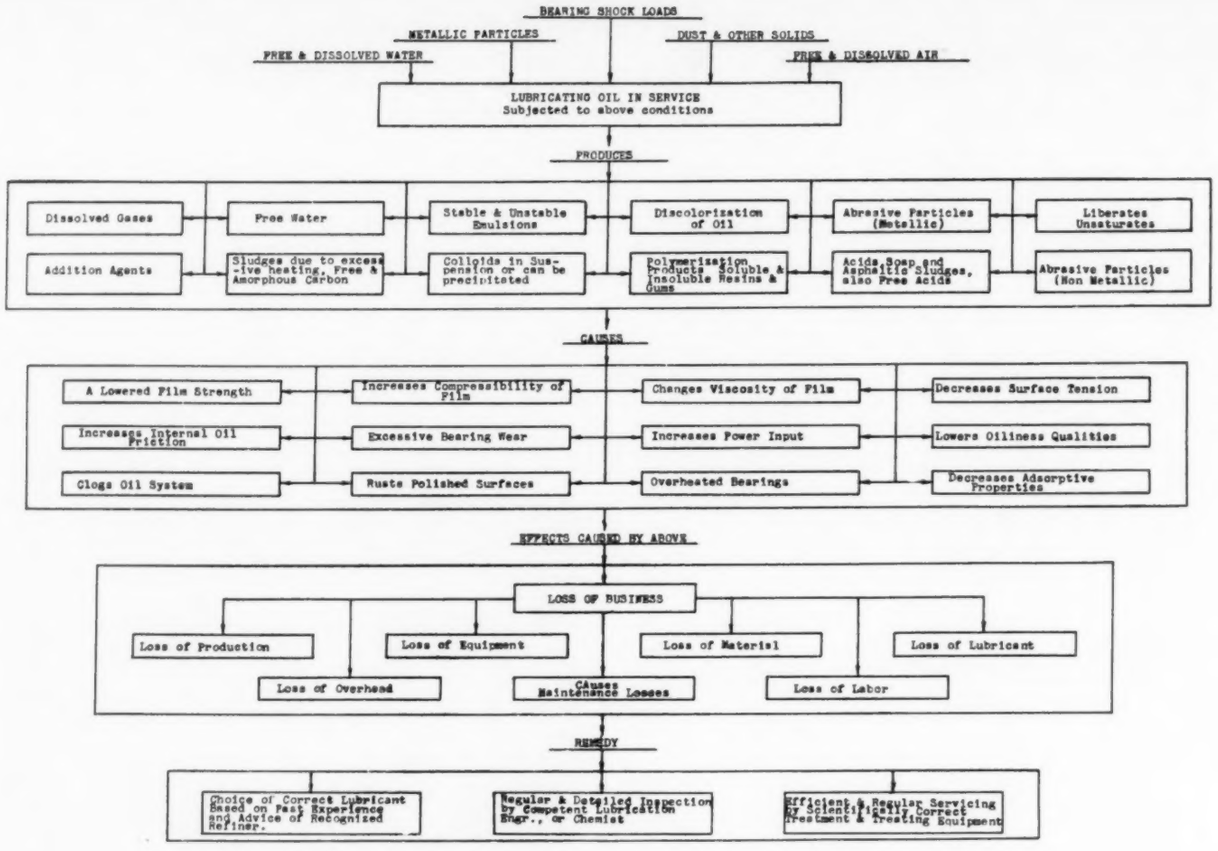

BEARING SHOCK LOADS
METALLIC PARTICLES
DUST & OTHER SOLIDS
FREE & DISSOLVED WATER
FREE & DISSOLVED AIR
LUBRICATING OIL IN SERVICE
Subjected to above conditions
PRODUCES
Dissolved Gases
Free Water
Stable & Unstable Emulsions
Discolorization of Oil
Abrasive Particles (Metallic)
Liberates Unsaturates
Addition Agents
Sludges due to excess -ive heating, Free & Amorphous Carbon
Colloids in Suspension or can be precipitated
Polymerization Products Soluble & Insoluble Resins & Gums
Acids, Soap and Asphaltic Sludges, also Free Acids
Abrasive Particles (Non Metallic)
CAUSES
A Lowered Film Strength
Increases Compressibility of Film
Changes Viscosity of Film
Decreases Surface Tension
Increases Internal Oil Friction
Excessive Bearing Wear
Increases Power Input
Lowers Oiliness Qualities
Clogs Oil System
Rusts Polished Surfaces
Overheated Bearings
Decreases Adsorptive Properties
EFFECTS CAUSED BY ABOVE
LOSS OF BUSINESS
Loss of Production
Loss of Equipment
Loss of Material
Loss of Lubricant
Loss of Overhead
Causes Maintenance Losses
Loss of Labor
REMEDY
Choice of Correct Lubricant Based on Past Experience and Advice of Recognized Refiner.
Regular & Detailed Inspection by Competent Lubrication Engr., or Chemist
Efficient & Regular Servicing by Scientifically Correct Treatment & Testing Equipment

**Fig. 1 shows graphically the agencies affecting lubricating of oils in service, their products, the results of contamination, their affects and remedies.**

7. WEAR LOSSES. Labor, babbitt and parts required because of wear of lubricated surfaces. $.....?

DIRECT COST OF LUBRICANTS

1. Cost of.....gallons of oil at $.....per gallon, for.....complete changes. $.....?
2. Cost of.....gallons of oil at $.....per gallon for make-up. $.....?
3. Cost of.....gallons of oil at $.....per gallon for sweetening, less value of oil withdrawn from system. $.....?
4. Drayage and overhead expense in connection with ordering oil. $.....?
5. Cost of servicing oil during operation. $.....?

Total Cost of Lubrication:

(a) Total hidden cost of lubricants..... $.....?
(b) Total direct cost of lubricants..... $.....?
Total cost of lubrication..... $.....?

This analysis should be made for each of the oils under consideration, taking data from previous experience in the plant or in the case of a proposed new installation, making estimates based on the experience in other plants.

## INSPECTION OF OILS

There is actually no method of testing oils chemically or physically to predicate definitely what service may be expected of them. Service is the only true test. However, it is of the utmost importance that regular inspection be maintained on all lubricants where so many factors are involved which relate directly to the operation of expensive equipment.

It is essential that at least monthly and preferably weekly records be kept of the condition of the oil, and a daily log of bearing temperatures also be maintained together with the amount of oil added to the lubrication system each day. The most important tests to be made at least weekly are—sediment, acidity, resistance to emulation, water content, ash present to indicate whether the wear of important parts has taken place to an appreciable extent, and viscosity. Methods for making such tests are very thoroughly described in the A.S.T.M. testing manual, which is readily obtainable to all lubrication engineers. However another test should be made, which is of extreme importance but which has been neglected materially in the past, due mainly to the cost of the apparatus necessary for making the test;—that is a miscoscopic examination. All oils should be examined periodically so as to determine visually or qualitatively the amount of suspensoids, such as finely divided solid particles, which are entrained in the oil; the appearance of emulsions and sludge particles in suspension in the oil. This can be made under proper conditions with a microscope and

a permanent record can be had of the same by the use of a photographic attachment.

## BEARINGS DESIGN

A great deal of attention has been given to the design of bearings for highly specialized service and heavy loading conditions by the manufacturers of such bearings; however, comparatively little thought has been given to the maintaining of the characteristics of the lubricant so as to maintain a constant film strength of the oil in such bearings during operation. In other words, bearings may operate very well under normal conditions for which they are designed with new oil; however, as soon as the oil is placed in service deterioration begins and the greatest variable in the entire lubrication system becomes apparent at once; namely, the essential characteristics governing the quality of the lubricating oil begin immediately to decrease at a more or less rapid rate and when no effective means for maintaining the quality is provided the design of the bearing is frequently blamed for the trouble.

## SYSTEM DESIGN

The design of the lubrication system is a matter which should be given great consideration inasmuch as there are many pitfalls to be avoided. Accessibility to all parts for cleaning is of paramount importance, high velocities in feed lines so as to keep them swept clean and prevent the formation and deposition of sludges is of prime importance. Adequately proportioned return lines from the bearings should be provided without being excessive; otherwise, condensation will occur on their interior and cause contamination of the oil.

Drainage of storage tanks should be provided for with properly placed outlets, so that proper drainage of sediment may be had, and the interior of such tanks always be kept as clean as possible.

Pockets should be avoided in the system where impurities may settle out and later be stirred up and contaminate the system at an exceptionally high rate. Provision should always be made for circulating the oil for purification purposes whether the equipment is in operation or not.

The selection of filters is of extreme importance, ordinary filtration is not sufficient. Filtration should be such as to remove the colloidal size particles from the lubricant so that in starting of the heavily laden bearings abrasion do not take place initially and in some cases injure the shafts and bearings beyond repair.

Air should be kept out of contact with the lubricant as much as possible so as to minimize the rate of oxidation of the oil. Steam coils for heating of the storage tanks should never be placed on the inside of the tank but rather on the outside, however, a jacketed tank is desirable. This not only eliminates the danger of steam leakage from the heating coils into the oil, but in the case of a jacketed tank properly designed gives a lower heat density per unit area of oil in contact with the heaters thus decreasing oxidation. Oil heaters of the tubular type should be so arranged that they are readily accessible for periodic cleaning and so designed that it is impossible for leakage of water to occur into the oil. Adequate temperature control should be installed on all heaters and coolers so as to maintain the lubricant at a constant temperature at all times.

## PRESENT METHODS OF PURIFICATION

The present methods of purification of lubricants, for most applications is pitifully inadequate when the investment in equipment is considered, and the fact that continuity of operation must absolutely be maintained to the highest degree possible.

The majority of filtration systems are such that they do not even accomplish ordinary filtration let alone ultra-filtration, but are simply methods of straining the larger sizes of impurities from the oil.

In general, oiling systems have been piped in solid without means being provided for thoroughly swabbing and cleansing the oiling system periodically.

It is essential in the maintenance of modern lubrication systems that all apparatus be installed in such a manner that they can be swabbed out and cleaned thoroughly at definite intervals. The length of such periods of service can be readily determined by actual operating conditions.

## SELECTION OF LUBRICATING OILS

Modern lubricating oils, as supplied by the major lubricating oil refiners, are usually of the highest grade and are generally suitable for the application as recommended by their engineers, provided they are serviced properly and kept in good condition. Manufacturers have spent many millions trying to produce oils to meet the increased demands placed upon them by exceptionally heavy duty machinery, with the result that the cost of refining oil has increased materially, The selection of specially adapted processes which concentrate the most advantageous qualities in the lubricating oils has resultated in greater expense to the lubricant manufacturer.

Therefore, it is paramount that the servicing of the oil on such equipment be such as to maintain it in the best condition possible.

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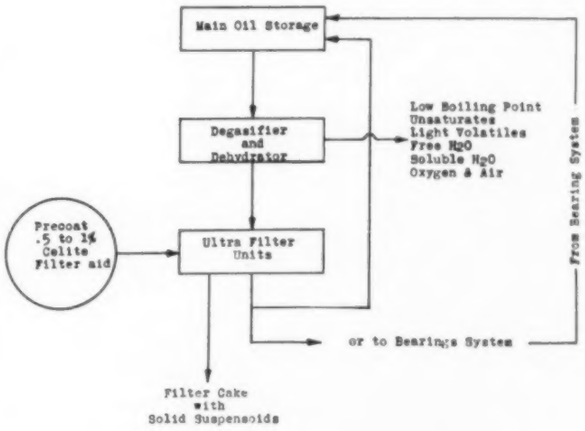
**Fig. 2 shows the flow diagram of a by-pass system for rolling mills and turbines.**


Main Oil Storage
Degasifier and Dehydrator
Low Boiling Point Unsaturates Light Volatiles Free H2O Soluble H2O Oxygen & Air
From Bearing System
Precoat .5 to 1% Celite Filter aid
Ultra Filter Units
or to Bearings System
Filter Cake with Solid Suspensoids

## TREATING SYSTEMS

It is the writer's opinion, as well as many others, that the ideal treating system is one which will maintain the oil continuously in the best possible condition so as to prevent oxidation, preserve film strength, prevent emulsions, and remove the exceedingly fine particles of solid constituents continuously during operation. This, however, does not entirely prevent the oil from oxidizing slowly and the formation of polymerized and resinous compounds of such a nature that makes it necessary to either abandon the oil after a limited period of service or make provision for completely re-refining the same so as to return it to the condition of new oil.

This can readily be accomplished by installing a central purification system which is capable of taking care of various classes of lubricating oil such as turbine oils, main mill bearing oils, reduction gear oils, pinion stand bearing oils, and oils from the bearings of large motors, converters, synchronous condensers, and such plants have been designed, placed in operation, and are of a very simple nature. They do not involve the many steps and the processes which are necessarily found in a refinery for refining oil from crudes. In this particular case we are simply re-refining a given fraction so as to remove the contaminants resulting from service, which is a very simple process but accomplished in practically same manner as the problem would be handled were the oil returned to the refinery for complete re-refining.

The cost of such equipment is such that where relatively large quantities of oil are used, it can be readily amortized within a relatively short period of time.

The purification of non-compounded reduction gear oil, to prevent excessive deterioration and wear, is just as essential as that of mill bearings or turbines due to the high stresses placed on the film of oil between the teeth of the gears, the shocks of which are necessarily transmitted to the film. In spite of all precautions, a certain amount of wear will exist under normal operating conditions, which will release extremely fine particles of metal from the gear itself, abrasive material from castings, and the products of oxidation, which should be removed immediately if long gear life is to be had and excessive wear on the gears is to be prevented.

The maintenance of film strength of such oils is just as essential for gear lubrication as for bearing lubrication on heavy duty equipment.

A well refined oil never wears out. It only becomes contaminated, and deteriorates very slowly in service depending on the severity of the operating conditions. It becomes contaminated with sediment, particles of metal, dust, etc., and may contain large quantities of water. Some of these are readily removed by the usual methods, but certain portions remain in the oil which are not separable by the usual processes of clarification. Oils have been re-refined many times and all known tests applied, including service, and have been found to fulfill the above condition in every detail.

## LUBRICATION REQUIREMENTS

In operation of heavy duty machinery, especially steam turbines and heavy mill machinery, which includes mill roll bearings, reduction gears, and pinion drives, correct lubrication is of major importance and should be one of the first considerations involved in the operation and maintenance of such equipments. This applies not only to the regular sleeve type of bearing but to anti-friction types of bearings (both ball and roller). The behavior of various lubricants and bearings has been the subject of many conflicting opinions as to the proper type of lubricants and their methods of application without thorough consideration being given to keeping such oils, while in service, in the highest state of purification possible.

Clower has stated that the required characteristics of lubricants for heavy duty service may be listed as follows:

A. Minimum gum-forming tendencies.
B. Minimum tendency to absorb moisture.
C. Freedom from abrasive materials.
D. Maximum oiliness.
E. High film strength.
F. Freedom from solidifying matter.

Under severe loading conditions where possibly the film may be ruptured, the property of oiliness is of prime importance, for under such conditions the film is an adsorbed one. A lubricant may possess a high film strength, but at the same time it may be deficient in oiliness; or conversely, it may possess oiliness to a high degree but lack film strength, oiliness and film strength while apparently, are not directly related or dependent on each other are of utmost importance.

Obviously, lubricants used in all types of bearings should be free from abrasive materials which tend to act as lapping compounds. Most lubricants are free from such materials when they leave the refinery, but in too many cases they become contaminated through careless handling, and carelessness in the operation of the lubricating systems. Drums and other containers are often left uncovered; pressure-gun connections are seldom if ever cleaned; oil retainers and seals are permitted to become worn excessively, thereby permitting the ingress of dust and dirt. In repair work bearings are frequently washed in dirty gasoline containing iron oxide, quartz, silica, and other abrasive materials. For long continued service of heavy duty bearings, clean lubricants are essential.

Solidifying matter not of an abrasive nature tends to clog oil passages, ducts, and the bearings themselves, thus causing unnecessary wear and friction by retarding the free movement of the parts. Gummy residue formed by the lubricant itself when subjected to high temperature and speed conditions act in a similar manner.

Moisture is decidely detrimental to all types of bearings, and its presence even in very small quantities has a more or less definite affect on film strength, due to emulsions formed in the oil, and the formation of deposits in the oiling system, and in the case of anti-friction bearings will cause rapid corrosion. For this reason, lubricants intended for bearings should be kept free of absorbed moisture.

From theoretical considerations it has been recognized that the friction in a lubricated bearing might

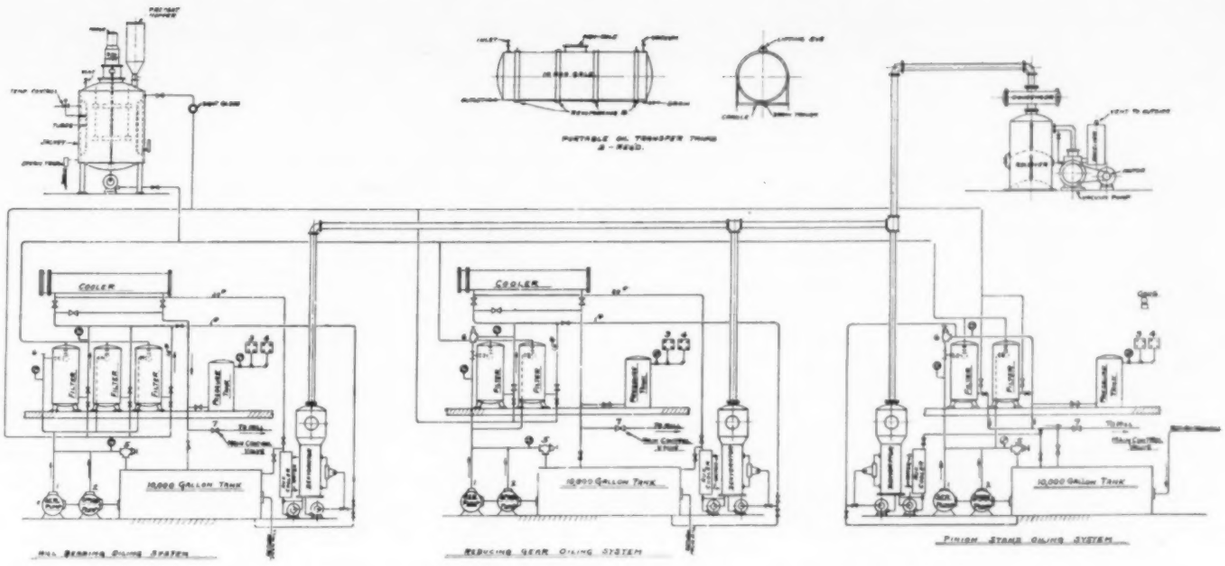



**Fig. 3 shows a complete rolling mill lubrication system, including central vacuum plant and the necessary treating equipment for the oiling system.**

be influenced by certain factors, among which may be listed:

The effect of viscosity of the lubricant,
The relative speeds of the moving parts,
The pressure normal to the surfaces,
The clearance between the surfaces,
The size and shape of the surfaces,
The materials and condition of the surfaces,
The supply of lubricant,
The method of applying the lubricant,
The nature of the lubricant.

It has been pointed out by Gruse that any film which does persist in the interface will depend for its existence upon the properties of the lubricant and the bearing metals primarily, not upon the speed of the journal or the design of the bearings.

He also states that the function of a liquid lubricant is then two-fold: first, at high speeds, to act as a supporting or cushioning medium between the rubbing surfaces, keeping them from actual contact and substituting the internal friction of the lubricant for the solid friction of the surfaces. The factors which determine the suitability of a lubricant for this purpose is its viscosity and film strength, and therefore since there is no universally accepted method or determining film strength we must depend principally upon the viscosity characteristics of the oil. However, these properties will depend upon the ease with which a pressure film is formed and the amount of power lost in this film, once it is formed. Obviously, a highly viscous oil will form and maintain a film more readily than one of low viscosity, but it will also cause a greater power loss than a thin oil because of its high internal friction. It is best to select the least viscous oil which will prevent undue heating.

The second function of a lubricant is to meet the demands of low speed and high pressure conditions corresponding to those encountered whenever any bearing system starts or stops. In such a case the speed is not high enough to induce the formation of a pressure film. The persistence of any lubricant between the bearing surfaces under load must be attributed to a specific property of the lubricant which causes it to resist expulsion from the interface by pressure. This specific property is known as lubricity or oiliness, and is defined by Herschel in terms of its effect, as that property which causes two lubricants to give different coefficients of friction, when their viscosities at the film temperature, and all experimental conditions are the same. It is the view of most modern students of the subject that this property of oiliness is due to a tendency of the lubricant or some constituent of the lubricant to become adsorbed on one or both surfaces at the interface, thus tending to saturate the attractive forces of the surfaces and to lower their capacity for cohesion. It has been pointed out by Wilson and Ries, also by Hardy, that such an adsorbed film would lose fluidity and resemble more or less closely a plastic solid. The failure to squeeze the material of such a film out from an interface by ordinary pressure could then be explained in terms of the ordinary plastic lubricant, such as a grease. At the near approach of the surfaces, the lateral equivalent of the pressure normal to the surface is below the yield value of the film material, and the film is not displaced. Whether or not the film may be regarded as a continuous one is open to question, but it does resist the efforts of pressure and friction to remove it. The actual existence of the film is indicated by some qualitative work of Wilson and Bernard.

Any discussion of the true cause of oiliness or of the nature of the assumed adsorbed film can be merely speculative. There is reason to believe that it need not be and often is not more than one molecule thick. The constitution of the molecules composing it is highly important. It is suggested by Woog that the property of unctuousness depends on the form, elastic rigidity, and resistance to rotation of the mole-

cules of the lubricant, together with its viscosity, surface tension, and degree of adsorption for the interface in question.

## FILM STRENGTH MAINTENANCE

The prime consideration in the operation of any bearing with a lubricant is the film strength. Unless the film strength is high enough to maintain complete separation of the metals, the bearing will fail. A few of the factors which cause the breakdown and decrease in film strength is the fact that emulsions are rapidly formed in the oiling system, have little or no lubricating qualities whatever; consequently low film strength, Aeration of the oil and the solution of harmful resinous and tarry compounds, which having little or no lubricating values materially decrease film strength. It is, therefore, essential that if the film strength is to be kept at the highest possible values, that the oil be maintained at all times free not only from free water but also water of solution, oxygen in solution, air in solution, as well as free oxygen and free air. A suitable process and apparatus is described herein.

The effect of extremely high shock stresses on films of the oil in bearings has been little investigated. It is believed by some that in the cases of contaminated oil films that these stresses reach such high values as to actually fractionate certain portions of the films; thus, greatly decreasing the film strength as well as contaminating the oil in addition. In other words, the shock values may be so great as to liberate water of solution and drive into the oil excess quantities of oxygen and sludge compounds so as to weaken the film strength materially.

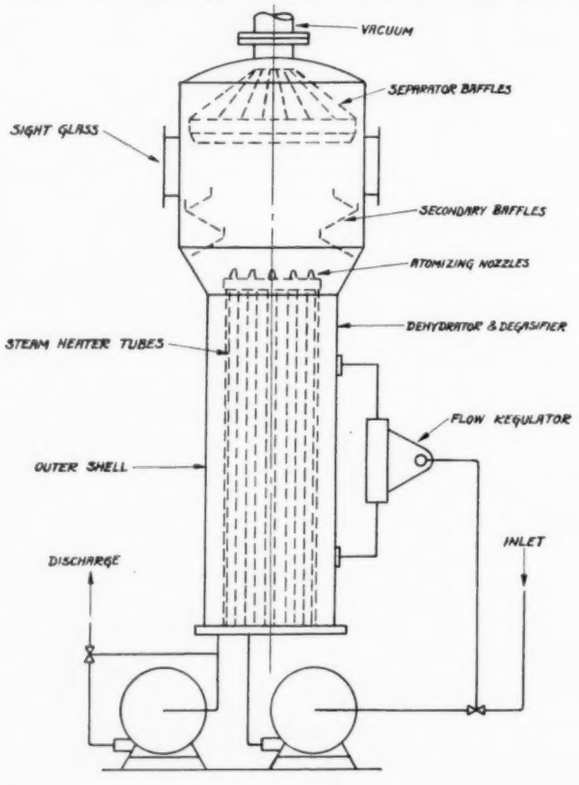
Another factor which enters largely into heavy duty bearing lubrication, which has not been given consideration in the past but which has been proven experimentally, is the fact that virtually all petroleum lubricants are compressible. The compressibility of an oil has a large bearing on the performance of oil films while in service. For example, a film may be of a definite thickness, that is we will assume .002″ or less, and have suspended in it extremely fine particles of iron oxide, metallic iron, bronze, dust or grit, which actually are more or less of a colloidal size and will remain in suspension in the oil and actually do no harm to the bearings as long as the film thickness is maintained. However, in the case of heavily laden bearings where extremely great shocks are predominant such as in steel rolling mills, the film on being compressed will permit such particles to establsih metal-to-metal contact between the shaft and the bearings, and result in an abrasive action. It has been noted to some extent that the film strength and the compressibility are more or less tied together. The film strength is, of course, dependent on the purity of the lubricating oil, or the fact that it is uncontaminated.

This is also true of the compressibility of the oil. In other words, when an oil which is thoroughly deoxidized, has all air and water removed from it, is compressible to some degree. However, it is much more compressible when contaminated with air, water, etc., and in addition shows a very marked decrease in film strength.

The proper lubrication system, embodying thorough dehydration, degasification and as well as ultra-filtration of the oil are of prime importance and will unquestionably remove such contaminants so that it is practically impossible to injure bearing surfaces due to the above causes.

The agencies affecting lubricating oils in service, their products, the results of contamination their effects and remedies for the same are shown graphically in Figure 1.

**Fig. 4 shows the degasifier unit consisting of the proper sized oil heater, pumps, flash chamber and separator baffles.**




## THE ACTION OF OXYGEN

It has long been known that all petroleum products are acted upon, even at ordinary temperatures, by the oxygen of the air. They become yellow and turbid, occasionally depositing flaky precipitates and usually acquiring an acid reaction. Little is really known of the detailed mechanism of oxidation.

Gurwitsch states that it is probable and that it is principally the unsaturated hydrocarbons and those of other groups with high molecular weights and branch chains which undergo exidation by the oxygen of the atmosphere.

The behavior of commercial petroleum products under the action of limited supplies of air and/or light involves several processes which in the main, lead to the formation of polymers or polymerized substances. Auto oxidation and polymerization induced by oxidation both play a part, and frequently it is difficult to say which is more responsible than the other for the effect produced (see polymerization).

Fischer-Schneider have observed various metals and their oxides, such as copper, iron manganese, etc., act as catalyzers and greatly accelerate oxidation.

## OXIDATION

Inasmuch as it has been observed that oxygen is one of the prime considerations affecting oxidation, it is well to remember that all used oil normally contains approximately 10% or more air of which 3% or more is oxygen in solution, as well as a small quantity of dissolved water. It has been determined that some merhods of purification which are ordinarily used seriously affect the amount of oxygen in solution. The special high vacuum treatment described herein, will remove more than 95% of this oxygen of solution, which inhibits any slow reaction between oil and oxygen thus tending to materially reduce the formation of sludge.

In removing the dissolved moisture from the oil, it is to be found that the film strengths are of a more persistent character, and it has been observed that there is little chance of breakdown of the film under high shock stresses.

## RESISTANCE TO OXIDATION

There is no one factor which has more effect on the quality, stability, and endurance of oil than its resistance to oxidation during service. Conditions favorable to oxidation exist in practically all lubricating systems, owing to the oil being circulated and agitated at changing temperatures while it contains air and water in suspension, as well as being in-contact with air at all times during operation. The tendency of all mineral oils is to oxidize under such circumstances and is greatly aggravated by the presence of minute particles of dust, sand, metals, etc., which act as catalyzers and sources of nuclear condensation. These actions are particularly marked when the type of oil contains unsaturated hydrocarbons, aromatics, sulphur, and other impurities, such as is found in poorly refined oils. In this case, it is subject to chemical reaction which darkens the oil in color which is accompanied by the formation of an emulsion in the presence of small amounts of water which might get into the lubricating system due to leakage of shaft packing, packing glands, water cooling devices, and the condensation of moisture from the air.

As the process of oxidation continues further, the slowly oxidizing oil accumulates sludge in solution until it is saturated, where upon sludge separates and forms insoluble precipitate of resinous, tarry character. Such a deposit of sludge is highly undesirable on account of partially clogging the oil passages, reducing the supply of oil to the bearings; the clearance between shaft journals and bearings is lessened by the deposit of hard tarry substances and the coils in the oil cooler become coated with sludge, materially affecting the efficiency of the cooler and increasing the temperature of the oil being fed to the bearings.

Since oxidation increases directly with the temperature and since any one of the above three conditions

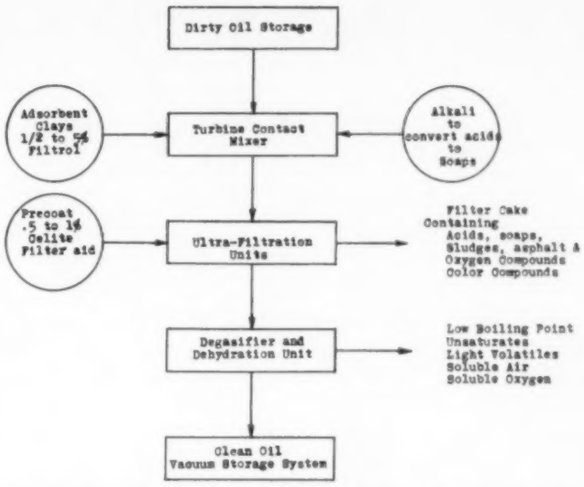

Dirty Oil Storage
Adsorbent Clays 1/2 to 5% Filtrol
Turbine Contact Mixer
Alkali to convert acids to Soaps
Precoat .5 to 1% Celite Filter aid
Ultra-Filtration Units
Filter Cake Containing Acids, soaps, Sludges, asphalt & Oxygen Compounds Color Compounds
Degasifier and Dehydration Unit
Low Boiling Point Unsaturates Light Volatiles Soluble Air Soluble Oxygen
Clean Oil Vacuum Storage System

**Fig. 5 shows Flow Diagram of the Central Oil Re-Refining System.**

causes higher bearing temperatures, it follows that the formation of the first sludge starts an endless chain, the sludge bringing higher temperatures which in turn cause more sludge. The ultimate result may be the burning out of the bearing and, the shutdown and repairing of the machinery.

It must be appreciated that the removal of such compounds during servicing or re-refining of the oil can scarcely be overestimated in importance. The removal of such compounds and foreign substances (contaminants) formed in the oil during operation is of utmost importance with respect to bearing operation and particular efforts should be made to effect their removal as rapidly as possible so as to maintain the best operating conditions for which the bearings are equipped and designed.

## POLYMERIZATION

Poorly refined oils are particularly susceptible to polymerization.

The capacity for chemical polymerization, that is, the combination of two or more molecules to form a large molecule of more complicated structure, is only possessed by the unsaturated hydrocarbons and unsaturated compounds generally, as it is the souble or three-fold linkages, which by their solution and mutual satisfaction render such combinations possible. Many unsaturated hydrocarbons are capable of polymerization at normal temperatures and without the action of any reagent. Heating generally greatly accelerates polymerization.

Gurwitsch also states that the polymerization of the unsaturated hydrocarbons which do not polymerize spontaneously at ordinary temperatures may be brought about by various catalysts such as iron and copper oxides; also that under certain circumstances the products of polymerization have themselves the property of promoting polymerization; also that traces of oxygen markedly increase the rate of polymerization.

Polymerized compounds are usually of a resinous nature and they may or may not be soluble in the

hydrocarbon; also as a general rule, remain in suspension in the oil. However, it may be said in general that they are oxygen containing compounds and sometimes sulphur containing compounds of unsaturated character and as such readily undergo various changes and have the property of drying readily, especially when exposed to air in thin films and when heated, and thus are detrimental for lubricating purposes.

## OIL SLUDGES

The life of mineral oil is intimately connected with the formation of deposits known as sludge, and the production of acidity upon which depends the life of a mineral oil. Oils obtained in the same shipment, placed in the same class of equipment and under similar operating conditions may differ much in their sludging characteristics. Some oils will deposit adherent sludges upon the coolers, and inside the piping systems, and in the bottom of storage tanks in a very short time, due to their rates of oxidation and various other causes.

The nature of these sludging phenomena are generally three-fold:

(1) The formation of sludge due to oxidation and polymerization.
(2) The reaction of liberated characteristic organic acids with certain metals to form soaps.
(3) The actual deposition of carbonaceous material due to carbonization caused by overheating.

The formation of sludge by oxidation of attackable oil with atmospheric oxygen is by far the most general case. This sludge gradually forms within the oil, and tends to become deposited in the cooler and in other parts of the lubricating system in an adherent honeycombed form because of the change in solubility of the sludge in the circulating oil due to the change in temperature at that point. The interstices or pores of this deposit become filled with loosely formed and finely divided precipitated sludge.

Examination of this form of deposit indicates it is an asphaltic compound rich in oxygen, which possess no free carbon, though at times it may appear quite black. When an oil is in contact with air, a constant source of oxygen is available to assist in the formation of sludge. Local heating, the presence of unsaturated compounds, and oxygen are the chief causes of the formation of asphaltic sludges.

A sludge of the second type may be deposited with the asphaltic sludge. The formation of this kind of sludge depends on the liberation of acids ($CnH_{2n}$-.$_2O_2$) and ($CnH_{2n}O_2$) by slow oil decomposition and their interaction with metals or oxides to form soaps. Such sludge appears dark brown to white in color. Small particles of this sludge aid greatly in raising the moisture content of the oil which is generally condensed from humid air in the oiling system. An approximate analysis of this kind of sludge gave 96.6% $H_2O$, and 3.4% dried sediment. The sediment consists of 11.3% $Fe_2O_3$, 1.4% CaO, 4.1% MgO, 13% of Na Salts 70% $H_2O$, and organic material which clearly indicates materials entirely foreign to the oil which have accumulated from impurities introduced into the system from other sources.

The carbon type of sludge which is due mainly to overheating the oil, breaks down the oil to amorphous carbon, saturated and unsaturated members lower in the series and to various gases. This type of sludge is very detrimental to lubrication.

In either case, the presence of a deposit in the oil should warrant immediate treatment.

## EMULSION FORMATION

Emulsion formation and demulsibility are quite closely connected, but should be considered separately in their relation to oils for heavy duty service.

In practically all cases a certain amount of water finds its way into the oiling system through various causes, and since such water is certain to be present, it is essential that the oil and water do not form any permanent emulsion. The circulation of an oil-water emulsion generally results in greatly impaired lubrication. Unless the emulsion is broken up and removed, the lubricating system becomes clogged, bearings overheat, the formation of sludges occur, and shutdown of the machine due to rupture of the oil film is the ultimate result.

The formation of emulsions takes place more or less readily and the emulsions formed are more or less stable, according to the character of the oil, its viscosity and gravity, the nature and quantity of its acid constituents, the temperature, etc.

To understand the principles of the formation of emulsions, it is necessary to study separately and apart two phases of this phenomena, namely, the formation of emulsions, and their maintenance. The formation is principally caused by two factors:

1. By violent mechanical agitation or pulverization.
2. By partial solution.

The first factor alone is capable of producing the finest oil emulsions, the average size of the oil particles may be close to $4.10^{-5}$CM.

It is, therefore, evident that violent mechanical agitation by continually presenting fresh oil surfaces, greatly facilitates rapid emulsification.

Bancroft formulated a very important rule regarding the formation of emulsions, "Water and oil or any other liquid immisible with water, may form emulsions of two kinds; either the oil being suspended in the water in fine drops, or vice versa."

In the first, the oil is named the dispersed or inner phase, and the water the dispersion medium or the outer phase, and in the second case vice versa. In the case of petroleum both these forms of emulsions are met with, though the second kind, with water as the dispersed phase is more frequently met with.

According to Bancroft's rule the so-called hydrophile colloids favor the formation with water as the outer phase, while the hydrophobe colloids cause the water to form the inner phase. So if an oil, for example, be agitated with an acqueous solution of soap, an emulsion of the first kind is formed, but if the water be agitated with an oil in which resinous substances have been dissolved, an emulsion of the second kind results.

Another condition which influences the formation and maintenance of emulsions, namely, the electric charge of the suspended drops. The presence of such a charge is only a special case of the universal law by

which the contact of two different substances, whether liquid or solid, is always accompanied by the development on them of contrary electrical charges.

## SWEETENING OIL

The Edison Electrical Institute Prime Movers Committee report that several power stations have tried and discontinued the practice of withdrawing old oil from turbine systems for the purpose of sweetening the batch with new oil and indicates that it is of little or no value. New oil seems to have a very strong solvent action on old oil and sludge which reduces the new oil to the same condition as the old rather than improve the old. This action is often indicated by excessive foaming when new oil is first added.

## THE RESTING OF OILS

Some believe that an oil may be reclaimed by resting. The committee considers this merely purifying the oil by allowing soluble sludge to become insoluble and settle out. Although the acidity may be lowered slightly, this is due to mechanical condition rather than to rejuvenating the oil. It has been proven that the acidity of the oil cannot be lowered by resting alone or by centrifuging and filtering or a combination of the two.

The Committee also states that the reclaiming of used turbine oil should be clearly distinguished from routine oil purification because there is a marked difference in the objectives. The purpose of the latter is to keep an oil in the best condition possible by removing all impurities and products of oxidation as quickly as possible, while the object of the former is to rejuvinate oil that has deteriorated. An oil unfit for service may be re-refined, although the regular methods of purification would not improve it.

## SCIENTIFICALLY CORRECT TREATING SYSTEMS —BY-PASS SYSTEM FOR ROLLING MILLS AND TURBINES

A treating system has been designed for continuously treating lubricating oils in large installations by the by-pass method for removing by means of a vacuum treatment, the volatile constituents of an oil which seriously affects its film strength, namely, the light ends of the lubricant which are liberated during operation, water of solution, free water, oxygen, and air by a central treating system. This is accomplished by means of a vacuum type dehydrator and degasifier which removes all the lighter boiling fractions continuously during the operation of the mill or turbine. These low boiling constituents are removed from the central system by means of a high efficiency vacuum pump and discharged directly to the atmosphere. This still leaves the colloidal like and heavier solids in suspension in the oil, which are removed by the proper type of filtration equipment which will be described later, namely, by ultra-filtration, so as to produce an oil which is microscopically clear of such contaminants.

The flow Diagram of such a system is shown in Figure 2. This illustrates the simplicity of such a system for accomplishing results which have never been attained before in such applications.

By referring also to Figure 3, a complete rolling mill lubricating system is shown including dehydration apparatus and the necessary lubrication equipment for the mill bearing oiling system, reducing gear oiling system, and pinion stand oiling system.

It is to be noted that the necessary transfer pumps, storage tanks, ultra-filters, dehydrators, coolers, and precoat mixing tank for the filters are all shown in their proper relation. This system, of course, is subject to slight variations based on actual operating conditions. The degasifier unit as shown in Figure 4 consists of the proper sized oil heater pumps, flash chamber, and separator baffles.

By referring to the drawing, it is to be noted that the operation of this unit is extraordinarily simple and the operation of dehydrating and degasifying the oil occurs without any high speed moving parts, or complicated mechanism. The operation of this unit is as follows:

It is to be remembered that the volatile impurities in oil which contains the water, both free and in solution, oxygen, and air, both free and in solution, as well as any other lower boiling contamints, all of which have a boiling point equivalent to, or lower than water and are quite readily removed when it is considered that the boiling point of water at sea-level at atmospheric pressure is 212°F., while under a vacuum of 29.95 inches of mercury, the boiling point becomes 34° F. This, however, is not the true boiling point of the mixture of oil and water which, of course, is somewhat higher, but still below the boiling point of water at atmospheric pressure, consequently, to remove the volatile contaminants by high speed distillation, it is necessary to supply the latent heat of vaporization. This is accomplished by means of a steam heater of the tubular type which is equipped with a series of atomizing nozzles so that the oil after receiving the latent heat of vaporization is projected into the flash chamber in atomized form, the small globules traveling upward at an exceedingly high velocity.

The flash chamber is also equipped with a series of separator baffles for separating the gases released therein from the oil globules, and permits the passage of the released gases to the vacuum pump without the entrainment of any oil globules, from whence the gases are exhausted directly to atmosphere. The baffles in turn having collected the globules which form in streams which drop down to a secondary set of baffles and return to the bottom of the heater chamber by gravity, from whence they are removed by the discharge pump and returned to the lubrication system.

It is to be appreciated that when the oil has been supplied with the latent heat of vaporization and is released in a highly atomized state in a chamber in which a vacuum of approximately 29½" is carried, that the entrained volatiles in each globule will be converted from liquid to gaseous state almost instantly, thus breaking down the film of oil surrounding them at a rate which is almost of an explosive nature, thus overcoming the surface tension of the liquid and preventing any frothing occurring during this process.

The necessary control equipment for accomplishing these results is a part of the installation and the

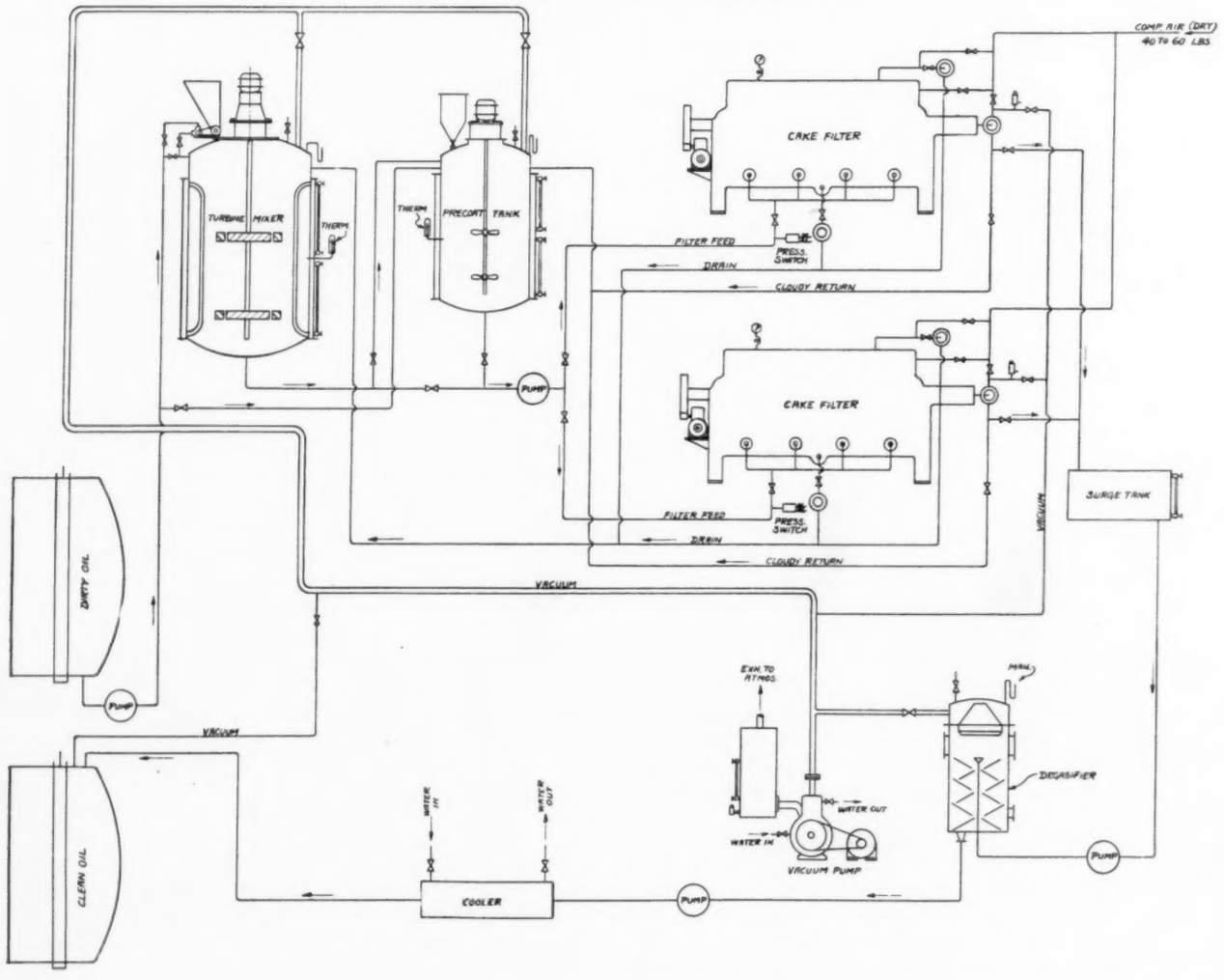
operation is entirely automatic in every detail. No cleaning is required with this apparatus. Thus far, we have removed only the volatile contaminants of the oil but have left therein the colloidal size suspensoids which consist of abrasive substances of various kinds and certain sludges which are readily filterable, providing the method of filtration is of such degree of fineness as to remove them.

The filtration equipment consists of a filter equipped with extremely fine Monel metal screens which are precoated with a filter aid known as Celite filter aid, which precoats the screens so as to provide the extremely fine capilarity necessary for ultra-filtration. A mixing tank with the necessary measuring hopper on the same and a circulating pump for accomplishing the precoating is provided.

Filtration as normally accomplished, even with blotter paper, is inadequate due to the fact that a large portion of the particles which act as a source of nuclear condensation and accelerators or catalyzers are not removed. Such small suspensoids including the metallic oxides may ruin a bearing on starting or stopping, or at any time the oil pressure is lost, and they will also have a tendency to collect in various low points or pockets in the lubricating system. The removal of such suspensoids really requires ultra-filtration. Such colloids which are normally less than one micron in size (one micron is 39/1,000,000 of an inch) are readily removed by proper filtration processes which have not been applied to ordinary operating systems. (The refiner has for many years used such a filtration process for removing such finely divided powdered materials, colloids and waxes from lubricating oils during manufacture). Such filtration will actually remove the turbidity of such oils. The precoat material has no effect whatever on the oil chemically and has the property of building up in the form of an exceedingly fine filter mat so that the filtration is actually a flow of the liquid through capillaries rather than through large openings such as occurs with fine screens and ordinary filtration. Such filtration also aids in breaking down emulsions at all times.

It has been found that the proper type of filter precoated with the proper type of filter aid is much more efficient and less costly in the long run from a maintenance and operating standpoint than any other method with which results are comparable.

**Fig. 6 shows the system of Re-Refining by Adsorption.**



The above arrangement accomplishes the removal of normal contaminants during operation of the apparatus in which the lubricant is used to an extremely high degree, much more so than has ever been accomplished heretofore. However, while greatly retarding the formation of acids and oxidation, does not prevent it entirely, so that after an indefinite period of operation the oil will discolor and show evidence of some oxidation with the resultant formation of soluble sludges, insoluble sledges, gums, resins, acids, etc., all of which have a higher boiling point than water and in many cases, higher than oil itself. If such oils are to be re-refined and used over again, they must be returned to the same condition as when the oil was received from the refiner. This operation calls for actually re-refining such oils by a scientific method which is well recognized by refiners and oil chemists, and actually consists in or removing the contaminants and conserving the remaining good oil for future use. Such methods are simple and practical and can be carried out with the proper equipment by unskilled operators.

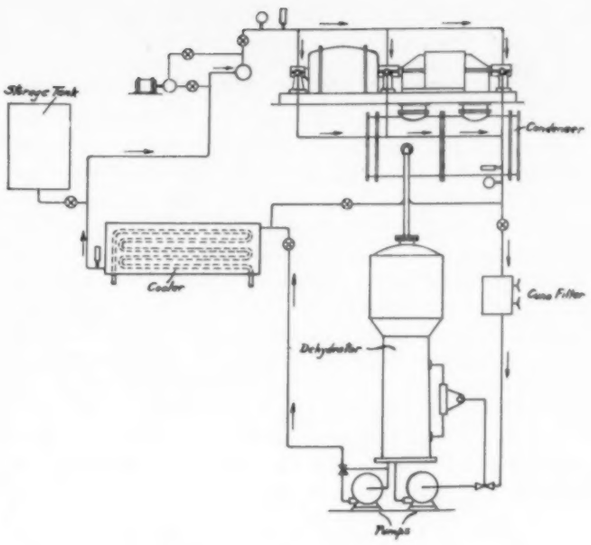



**Fig. 7 shows the turbine lubrication system.**

## RE-REFINED OIL

It is of particular significance that in the case of so-called "re-refined oil", that the performance in actual service has been found to be rather exceptional.

Parish and Cammen state that it has been found experimentally that only certain portions of an oil are capable of oxidation. Moreover, only certain portions of an oil are capable of forming the gummy substances designated in various instances by such names as asphaltines, waxes, gums and resins. If an oil is uesd under heavy loaded bearing conditions, which is subject to high speeds and shocks, it is exposed to conditions, which produce oxidation of the oxidizable constituents, and the formation of gum by the gum-making constituents.

Oil which has been used in a lubricating system after having sludges and gums extracted from it to as great an extent as possible, will, upon being returned to the lubricating system, be found to give as good service as it did originally. This, of course, is dependent upon the extent to which it was originally contaminated, and the completeness with which the contaminants have been removed. Once the constituents subject to oxidation and the formation of gum have been so effected, very little further action of this kind can take place. If, therefore, the first term of service of such an oil results incomplete oxidation and gum formation, and if these oxides and gums have been completely removed, the result will be a superior lubricant because of its ability to maintain within the cavities of the metal surface a reservoir of pure lubricant which will be free from the more powerfully adsorbed sludges and gums. Furthermore, it will actually be capable of cleansing a dirty lubricating system by dissolving the sludges and gums already present due to its solvent action without exceeding its own limit of saturation.

Resinous and asphaltic substances are strongly reactive toward adsorbents, a property which is utilized in treating the oils for color, and, in certain cases, in removing pitchy substances from cracked oils, or for general purification purposes.

Adsorbents remove strong acidic substances, such as sulfuric acid and sulfonic acids, from oils, while nitrogen compounds are to a certain extent removed from the oil by various adsorbents.

This phenomena has made it possible to produce the high grade lubricants which are in use today.

For those who are not familiar with the process of adsorption the explanation as given by Gurwitsch follows:

"The decolourising properties of bone charcoal, Florida earth and similar finely porous substances which have been known for some decades, meet with continually increasing application in the petroleum industry, and these substances have become indispensable in the preparation of many petroleum products. The physical-chemical process named adsorption, which underlies the action of finely porous substances, has been exhaustively studied by many investigators, particularly during the last few years. It would lead us too far to give a description here of even the principal of these general researches. Readers who wish to study this subject may be referred to the exhaustive treatises of H. Freundlich, "Kapillar-Chemie," and W. O. Ostwald, "Grundriss der Kolloidchemie." The fundamental theory will be here only very briefly treated, more detailed attention being only given to questions which appertain to the field of petroleum chemistry.

"It has been proposed by Freundlich that under the general term adsorption shall be understood any change in the concentration of a solution at its surface, whether that be the limiting surface between the solution and another liquid or solid phase. By deduction from pure thermo-dynamic condiserations Gibbs formulated the law known by his name in the eighties of last century. According to this law, in all cases in which

the dissolved substance changes the original surface tension of the pure solvent its concentration in the thin surface layer must be other than that existing in the remaining mass of the solution, and the concentration must change so as to make the surface tension a minimum. In other words, if the surface tension of the pure solvent be depressed by the dissolved substance, the latter has a tendency to concentrate at the surface of the solution, and the concentration at the surface layer will become greater than that of the rest of the solution, and vice versa. Therefore, when a solid substance is introduced into a solution, and the surface tension at the limiting surface of these two phases falls as the solution becomes more concentrated, the concentration will here actually increase, and correspondingly decrease in the rest of the solution. If the surface of the solid be sufficiently large, the impoverishment of the solution may be susceptible of direct determination.

"The Gibbs-Freundlich theory of adsorption is at present almost generally accepted. Nevertheless it appears to be proper in those cases which deal with adsorption by solid bodies, to regard these problems not from the point of view of energy but of mechanics.

"From the mechanical point of view the process of adsorption may be regarded as one of the various expressions of that physical-chemical force of attraction which acts on the molecules of all chemical compounds, even the so-called saturated ones, and causes mutual attraction between both similar and dissimilar molecules. In cases of the attraction of liquids by porous solid substances the heat of moistening may serve as an approximate measure of this force.

"To return to the adsorption process, the action appears to be as follows: When the adsorbent comes into contact with a solution it attracts molecules of the dissolved substances as well as those of the solvent to its surface. As a result of this attraction films consisting of condensed molecules are formed about the particles of the adsorbent, and the dimensions of these films are determined by the radius of action of the adsorbent. The proportion of the molecules of the dissolved substance and those of the solvent in this film are determined, in the first place by the proportion of the two kinds of molecules in the solution, and secondly, by the force with which one and the other are attracted by the adsorbent. When therefore, one and the same adsorbent acts upon equally concentrated solutions of various substances in the same solvent, the one which is most strongly attracted by the adsorbent is adsotbed to the greater degree. If, on the other hand, we take equally concentrated solutions of one and the same substance in various solvents, the substance is most strongly adsorbed from the solvent the attractive power of which for the given adsorbent is the least. Thus in adsorption there may be said to be a contention between the molecules of the dissolved substance and those of the solvent as both strive to attain the greatest possible concentration at the surface of the adsorbent.

"These two rules, together with what has already been said on the general character of the force of physical-chemical attraction, render it possible to predict many of the phenomena of adsorption, and so to control these processes to a certain degree; and in this consist the advantages of the mechanical view of adsorption here set forth over the energy theory of Gibbs-Freundlich. As a matter of fact the decisive factor in the process of adsorption according to this theory is the change in surface tension by the dissolved substance at the limiting surface between the adsorbent and the solution.

"If we consider adsorption from the standpoint just set forth, for the magnitude of the force of physical-chemical attraction may be approximately estimated by the above rules.

"We will now consider the behaviour of various constituents of petroleum with decolourising earths from this point of view. The greatest interest centers on the adsorption of resinous and similar substances, which give their colour to petroleum products and in general are to be regarded as detrimental and undesirable constituents. As we know, these substances are acid-containing, partially unsaturated, and belong to those constituents of petroleum with the highest molecular weights. On the basis of what has been said above we may therefore expect that petroleum resins and asphalts will be adsorbed in a particularly high degree, and this has actually been confirmed by experiment and in practice. Activated clays, for example, can absorb up to 12% of its weight of resinous substances and of this 9% to 10% is so tenaceously held by the clay that it cannot be extracted even by a great excess of benzine (irreversible adsorption). In the various fractions of the same petroleum oil resinous substances are contained which, while belonging to the same chemical group, possess different oxygen contents, iodine value, molecular weight, etc., these values always increasing as we ascend the series of fractions. It may, therefore, be expected that the resinous substances contained in the cylinder oil distillate will be more readily adsorbed than those of the machine oil distillate; these more readily than those of the spindle oil distillate, and so on.

"All that has been said above refers also to the adsorption of naphthenic acids, which are very readily adsorbable owing to their content of the carboxyl group. Here also the acids of high molecular weight are more readily adsorbed than those of low molecular weight.

"The naphthenic acids, however, are also to some extent irreversibly adsorbed.

"The behaviour of the nitrogen and sulphur compounds of petroleum as regards adsorption is as yet little investigated, but it is known that they are pretty readily adsorbed.

"As regards their capacity for adsorption the unsaturated hydrocarbons are followed by the aromatic hydrocarbons and then by the naphthenes, whilst the paraffin hydrocarbons are most feebly adsorbed. As stated above, the factor of molecular weight has a great influence on this process."

It is on the aforementioned practice that the process of re-refining described herein is predicated.

## CENTRAL RE-REFINING PLANT

A central treating plant is provided for re-refining the oils after definite periods of service when it is found that the acidity of such oils and the amount of sludge has increased beyond recognized working limits and which are not removed by the continuous by-pass system on the mill or turbine equipment.

By referring to Figure 5 flow diagram, and the schematic piping diagram Figure 6 for Central Oil Re-Refining Systems, it is to be noted that re-refining is a very simple operation, viz:—

The oil is pumped continuously from the dirty oil storage tank by means of a centrifugal pump, under a positive pressure, through a hydraulic motor, which drives a proportioning feeder for feeding the activated clays into the turbine mixer, at a rate proportional to the volume of oil being treated continuously. The hydraulic drive motor discharges the oil into the turbine mixer where the oil and the activated adsorbent from the feeder is contacted at definite rate, velocity and temperature.

The process of adsorption is then taking place as described here-to-fore, thus adsorbing into the clay the products of oxidation, viz; acids, asphaltines, soaps, sludges, etc.

The oil then passes to the precoat tank (which has been previously used to precoat the filters) where a slight amount of alkali is introduced and commingled with the oil in the presence of the adsorbent, so as to convert such acids, which were not readily adsorbable in their original state to soaps, which is quite readily adsorbed, thus, producing a finished oil having an exceptionally low acid value.

It is to be noted that during these steps of the treatment that a vacuum has been maintained on the turbine mixer and the precoat tanks, thus, removing the low boiling contaminants, such as water, kerosene, gasoline, etc., by means of the vacuum pump, from whence they are discharged to the atmosphere or they may be recovered, by means of a condencer and used for penetrating oil or as fuel oil.

After treatment with the activated adsorbent and alkali the oil is pumped through the filters, which have been precoated prior to this operation.

The precoating tank is also used for mixing the precoating material which forms an extremely fine coating on the Monel metal screens which give the finest degree of filtration possible and which we will describe as ultra-filtration. (Such a method of filtration has long been in use by sugar manufacturers and oil refiners at their refineries for the filtration of extremely fine particles of solid material from their oils as polishing operation after processing the oil.)

The cake is removed at definite intervals thus removing the activated clay with the adsorbed impurities which consists of the acids, soaps, sludges, asphalt and oxygen compounds as well as color compounds. The filter cake is disposed of and no further means for recovering, or re-use is made due to its low initial cost.

After filtration through the ultra-filter units, the oil is passed through a degasifier and dehydration unit which removes any of the low boiling point unsaturates, light volatiles, soluble air and soluble oxygen which may have remained in the oil during processing, or has been picked up during the process. The oil is then discharged into the storage tanks which are also usually maintained under a vacuum to prevent any deterioration occurring whatever during storage, namely, sweating of the tanks, or the slow oxidation which occurs during storage. The oil then will be found to be in extra-ordinary good condition. (It has been known for a considerable period of time that oils stored under a vacuum do not deteriorate over exceptionally long periods of time.)

The above method of re-refining applies to all non-compounded lubricating oils of any nature and the capacity of such a system is really the function of the viscosity of such oils.

## TURBINE OILS

Turbine oils which are contaminated by water and oxidized products and usually with very little solid materials are readily kept in an extraordinary high speed of purification by continuously hydration by means of the dehydrator as shown in Figure 4, being connected into the turbine lubrication system as illustrated in Figure 7. No vacuum pump or central vacuum system is required in such a system, inasmuch as the vacuum from the condenser can be used, although a central vacuum system which consists simply of a cooler, a receiver and a vacuum pump is recommended.

An operating record of this class of application on a 20,000 KW turbine shows practically no deterioration of the oil over a five year period.

It has been proven that such oils after extremely long periods of use require re-refining if they are to be re-used and the method outlined above is entirely satisfactory in every detail for accomplishing the desired results.

## BIBLIOGRAPHY


"*American Petroleum Refining*", H. S. Bell, C. E., D. Van Nostrand Co., New York City.

"*Petroleum and Its Products*", Wm. A. Gruse, PhD., Mellong Institute of Chemical Research, McGraw-Hill Book Co.

"*Chemical Refining of Petroleum*", Vladimor Kalichevsky, Research Laboratory, Socony-Vacuum Corp.
Bert Allen Stagner, Mellon Institute of Industrial Research.
Chemical Catalog Co.

"*Proceedings of Edison Electrical Institute*" 1929 to 1935
Petroleum Technology
Scientific Principals by Dr. Gurwitsch and Harold Moore, D. Van Nostrand Co., New York City.

"*Iron Age*", October 3, 1935

"*Lubrication of Anti-friction Bearings*", James I. Clower
Engineering Bulletin No. T-39
Technical Division, Standard Oil Co. of Indiana.

"*The Chemical Mechanism of Lubrication*", Wm. F. Parrish and Leon Cammen, A. S. M. E. Paper, December 5,1932

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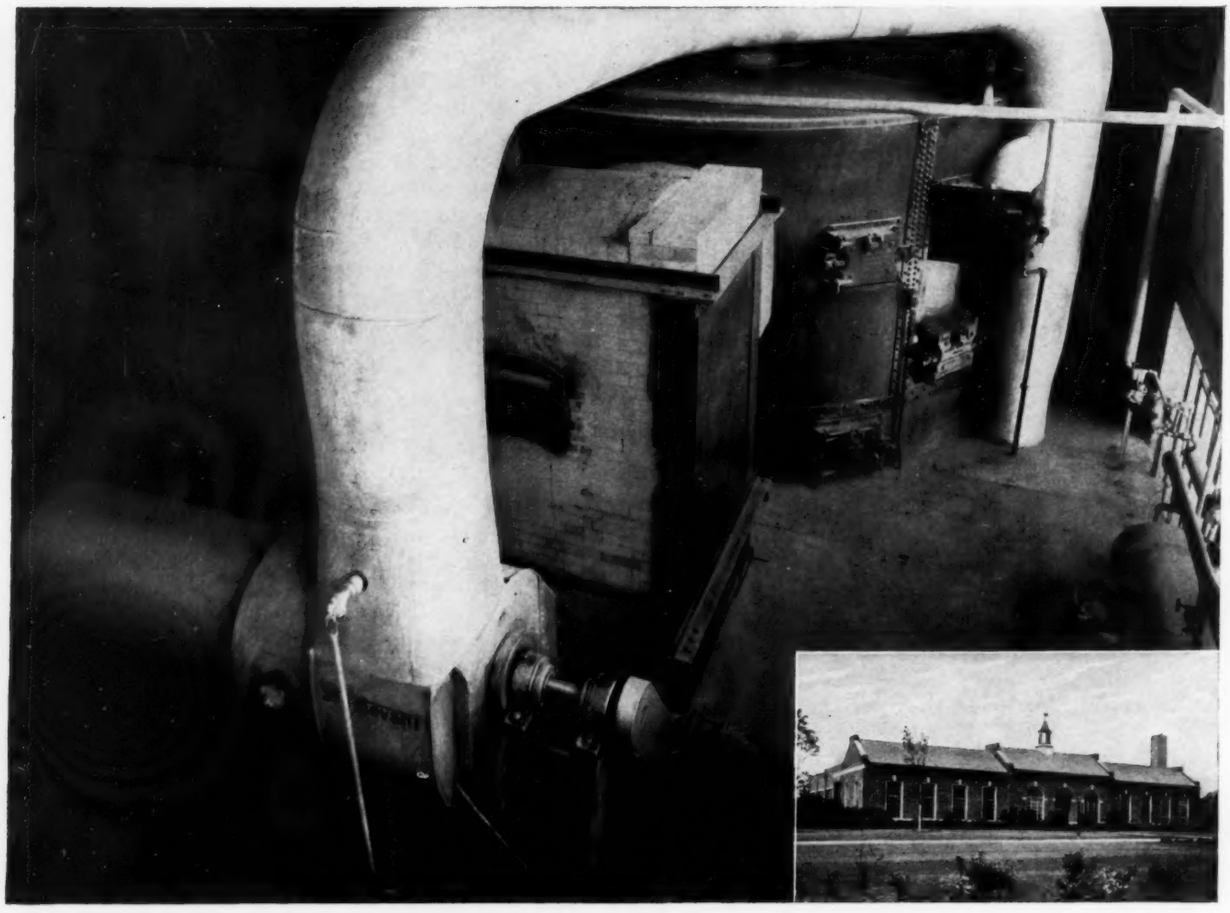

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*President,*
Salem Engineering Company,
Salem, Ohio.

**Joseph Kinney, Jr.,**
United Engineering & Foundry Co.
Pittsburgh, Penna.

**Herman Pfaff,**
*Electric Foreman,*
Carnegie-Illinois Steel Corp.
Gary, Indiana.

**E. W. Ritchie,**
*Engineering Department,*
Carnegie-Illinois Steel Corp.
Gary, Indiana.

**Frank Roberson,**
*Assistant Electrical Engineer,*
Carnegie-Illinois Steel Corp.
Gary Works, Gary, Indiana.

**E. W. Steinweg,**
*Superintendent Coke Plant,*
Youngstown Sheet & Tube Company,
East Chicago, Ind.

**Jay P. Moore,**
*Salesman,*
Electric Controller & Mfg. Co.
Cleveland, Ohio.

**Chas. D. McCord,**
*Sales Representative,*
Electric Controller & Mfg. Co.
Cleveland, Ohio.

**T. R. Rhea,**
*Engineer,*
General Electric Company,
Koppers Building,
Pittsburgh, Penna.

**Chas. A. Richardson**
*Sales Engineer,*
United Engineering & Foundry Co.
Pittsburgh, Penna.

**Maurice P. Sieger,**
*Assistant Chief Engineer,*
United Engineering & Foundry Co.
Pittsburgh, Penna.

**Walter P. Schmitter,**
*Assistant Chief Engineer,*
Falk Corporation,
Milwaukee, Wis.

**W. C. Wilkinson,**
*Sales Manager,*
Rowan Controller Company,
Baltimore, Md.

**C. E. Weinkauf,**
*Representative,*
Hodson Corporation,
Pittsburgh, Pa.

**Lee Wilson,**
*President,*
Lee Wilson Engineering Co.
Cleveland, Ohio.

**D. I. Shontze,**
*Mechanical Engineer,*
Corrigan-McKinney Works,
Republic Steel Corp.
Cleveland, Ohio.

**Geo. C. W. Sturgess,**
*Electrical Foreman,*
Carnegie-Illinois Steel Corp.
Gary, Indiana.

**R. R. Thomas,**
*Assistant Chief Engineer,*
Tennessee Coal, Iron & R. R. Co.
Ensley, Alabama.

**S. William Stouffer,**
*Millwright Foreman, 14" Rolling Mill,*
Jones & Laughlin Steel Corp.
Aliquippa, Penna.

**Frank C. Winters,**
*Representative,*
Electric Controller & Mfg. Co.
Cleveland, Ohio.

**Ralph B. Kraft,**
*Salesman,*
Birdsboro Steel Foundry & Machine Co.,
Birdsboro, Penna.

**L. R. Lindsley,**
*Salesman,*
Automatic Transportation Co.
Chicago, Ill.

**H. C. Funk,**
*Chief Draftsman,*
E. W. Bliss Company,
Salem, Ohio.

**Edward Ryan,**
*Salesman,*
Anaconda Wire & Cable Co.
Pittsburgh, Penna.

**R. S. Glenn,**
*Sales & Application Industrial Control Apparatus*
General Electric Company,
Schenectady, N. Y.

**Jay J. Seaver,**
*Vice-President,*
H. A. Brassert & Company,
Chicago, Ill.

**Arthur M. Grasse,**
*Manager, Industrial Manufacturing Division*
Goodman Manufacturing Company,
Chicago, Ill.

**M. M. Rose,**
*Secretary,*
Columbia Electric Manufacturing Company,
Cleveland, Ohio.

# ▲ ▲ ▲ ITEMS OF INTEREST ▲ ▲ ▲

**William P. Ewing,** who has been with the Superior Steel Corporation since 1918, has been made executive vice president, a newly created office. Mr. Ewing has advanced with the company in successive steps, having held the positions of assistant manager of sales ,manager of sales, and in October, 1935, he was made vice president in charge of sales, taking the place of the late John E. Wetzel.

▲

**L. W. Briggs,** who resigned early last month as general manager of sales of West Leechburg Steel Company, has been made vice president in charge of sales, of Superior Steel Corporation, succeeding Mr. Ewing. Mr. Briggs had been with the Leechburg Company since 1917, with the exception of 1½ years of over-seas service in the World War. He served the company as district representative in Detroit for a year and a half and as Chicago representative for 13 years. He was made general manager of sales in 1933, which position he held until his resignation.

▲

**David Pryde** has been made vice president in charge of operations of the Superior Steel Corporation. Mr. Pryde began his career in the steel business in 1894 with the Edgar Thompson Works of the Carnegie Steel Company. He later was made superintendent of the lower city mills of that company, and then assistant general superintendent of all city mills. He joined the Superior Steel Corporation in 1928, as manager of works, which position he held until his election to his present office. Mr. Pryde is also a director of the company.

▲

**John C. Wise,** formerly of the New York Office of the Rockbestos Products Corp., has been appointed Manager of the new Cleveland District with headquarters at the Union Trust Building, Cleveland, Ohio.

**H. C. McElhone,** who has served in various capacities in the works, headquarters sales, stock control and executive departments, has been appointed assistant to vice president of the Westinghouse Electric and Manufacturing Company.

Associated with Westinghouse since 1919, Mr. McElhone for the past five years has been attached to the President's office. In recent months he has been in charge of Westinghouse Golden Jubilee Year activities.

▲

**K. C. Gardner,** vice president, United Engineering & Foundry Co., recently left Pittsburgh for an extended trip to Europe.

▲

**Joseph A. Miller,** master mechanic, Youngstown Sheet & Tube Co., Youngstown, O., has retired, after 35 years association with the company, many of which were spent in new mill construction. Going from Lebanon, Pa., in 1901, he built Sheet & Tube's first puddle mill, old sheet mill, and erected the original blooming and skelp mills.

▲

**F. P. Shephard** has been appointed district sales manager of the Cleveland office of Haynes Stellite Company. Mr. Shephard will take over the position formerly accupied by W. A. Moore whose death was a shock to his many friends in the metal-working industry.

Mr. Shephard has been associated with the cutting tool industry for more than 20 years, and for the past 9 years has been sales engineer in the Chicago office of Haynes Stellite Company.

WILLIAM P. EWING

L. W. BRIGGS

DAVID PRYDE

# MATCH THESE ECONOMIES— *if You Can*

Modern Elwell-Parker System transports rolls of strip steel between pickler, storage or cold roll, scales, and rotary shears. One truck to each operation.

Average weight of loads transported per trip (one roll), 8,000 to 12,000 pounds.

Average number of round trips made by each Truck per hour, 5.

Average size of rolls, 50" long x 35" outside diameter.

Approximate distance covered by each Truck in 24 hours, 7 miles, including backing to make turns.

Approximate weight of loads handled by each Truck per 24 hours, 1,200,000 pounds.

Trucks steer easily. Operators do not become fatigued.

Continuous service is vital. If Trucks stop, production must stop. Elwell-Parker Trucks have not failed.

THESE PICTURES of efficient coil-handling in a modern steel plant, fairly shout at you: "Materials-handling costs here have been cut to the last cent!"

Indeed they *have* been, with many other gains besides, since three Elwell-Parker Ram Trucks, gas-electric driven, have started handling coils of strip steel 24 hours a day. They link three major processes into one smooth, connected flow.

The Elwell-Parker System transports coils or rolls of strip steel from (1) pickler to stock storage or cold roll; and (2) thence to scales and storage; and (3) to rotary shears. One "key" Truck handles each operation and is responsible for it. Loads do not pile up at "bottle-necks" in *this* System.

Such wholesale economies are the sign of the low-cost plant. Is yours one of the *lowest*-cost? Elwell-Parker Engineers will tell you whether you are paying too much for your load-moving—and if so, will show where your profits can be increased. Why not write today?

The Elwell-Parker Electric Co., 4504 St. Clair Avenue, Cleveland, Ohio.

**Of course you will install the proven Elwell-Parker System in your new mill. For your present mill, call in an Elwell-Parker Engineer to consult with your operatives to determine what savings you may realize by a similar installation there.**

## *New* ELWELL·PARKER *Trucks*

ESTABLISHED 1893 • BUILDING POWER INDUSTRIAL TRUCKS SINCE 1906

**J. E. Johnson,** as announced by the Carnegie-Illinois Steel Corp., has been appointed the Director of the Department of Training. Mr. Johnson is an active member of the Association.

The purpose of this department is to give opportunity to employees and their sons to receive practical and technical training which will enable them to qualify for better positions.

This department will have jurisdiction over all apprentice and sales training schools in the several Plants, and will come under the general supervision of Mr. Ross L. Leffler, Manager of Industrial Relations.

Mr. Johnson is a graduate of the Carnegie Institute of Technology. He has been director of the continuation school of McKeesport; member of the faculty of the McKeesport High School; Director of vocational education at Jeannette; a member of the faculty of the Pennsylvania State College conducting engineering extension work at the Clairton High School. He has been connected with the engineering department of the Clairton Steel Works since 1931. In consequence, he is exceptionally well-qualified for his new position.

J. E. JOHNSON

▲

**Edward A. Livingstone** has recently been appointed manager of alloy tube sales for The Babcock & Wilcox Tube Company, Beaver Falls, Pa. Prior to this appointment, Mr. Livingstone was engaged in the development and introduction of special B&W high-temperature, corrosion-resistant alloys to the oil industry in the United States.

Before becoming connected with The Babcock & Wilcox Tube Company, in January, 1933, Mr. Livingstone was successively district sales manager for the A. O. Smith Corporation in Los Angeles, Tulsa, and New York City. This experience and that acquired in the last 4½ years with The Babcock & Wilcox Tube Company in special sales work in the oil industry, gives Mr. Livingstone a broad background for his new position.

**Morris E. Leeds,** President of Leeds & Northrup Company, Philadelphia, was the recipient this year of the Henry Laurence Gantt Gold Medal awarded annually by the Institute of Management "for distinguished achievement in industrial management as a service to the community". Henry S. Dennison, who received the award in 1932, presented the Medal to Mr. Leeds at a joint dinner of the Institute of Management and the American Management Association held in New York on June 14.

Long a keen student of human relations in industry, Mr. Leeds is widely known for his far-sighted philosophy of the factors which underlie harmony between employer and employee. The Leeds & Northrup Company which he founded in 1899, now recognized throughout the world as leading manufacturers of electrical measuring instruments for scientific use and of apparatus for industrial measurements and control, has been the proving ground for Mr. Leeds' forward-reaching ideas. In a growing business, over a period of years, the sound practicability of a progressive managerial policy has been amply demonstrated.

MORRIS E. LEEDS

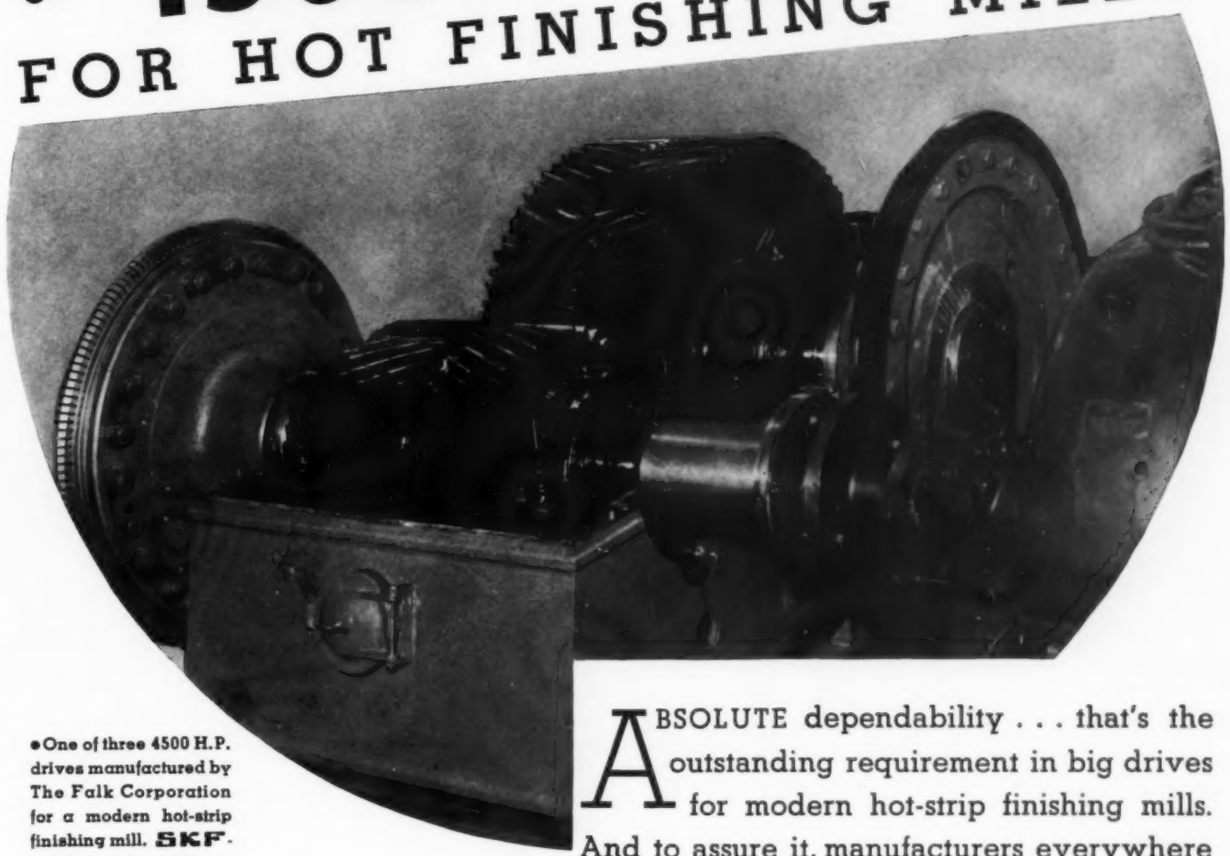
▲

**S. C. DuTot** has been appointed district manager of the Chicago office of the Electro Metallurgical Sales Corporation. Mr. DuTot has been associated with the ferro-alloy business for more than 20 years. For the past 12 years he has been engaged in the sales activities of Electro Metallurgical Sales Corporation in New York and Chicago. Prior to 1924, he was employed as chemist at the Niagara Falls of Electro Metallurgical Company, another unit of Union Carbide and Carbon Corporation.

▲

**John Frabel** formerly mechanical foreman Pittsburgh Steel Company, Monessen, Pa., has been appointed assistant master mechanic of the steel works department.

# SKF SPHERICAL ROLLER BEARINGS on 4500 H.P. DRIVES FOR HOT FINISHING MILLS

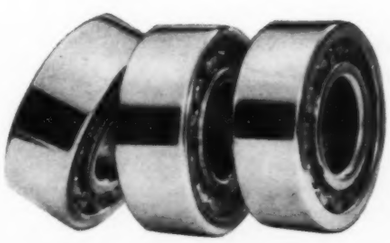


• One of three 4500 H.P. drives manufactured by The Falk Corporation for a modern hot-strip finishing mill. SKF-equipped throughout.

3634

ABSOLUTE dependability . . . that's the outstanding requirement in big drives for modern hot-strip finishing mills. And to assure it, manufacturers everywhere are adopting SKF Spherical Roller Bearings for this important service.

The self-aligning characteristics of SKF Bearings eliminate overloads caused by misalignment and do away with adjustments for the negligible amount of wear. All the way through, SKF's assure correct gear alignment . . . reduced starting friction . . . rock-bottom maintenance. Next time you buy bearings, come to SKF.



SKF

ROLLER BEARINGS

SKF INDUSTRIES, INC., FRONT ST. & ERIE AVE., PHILA., PA

ADVERTISING PAGES REMOVED

**George Endicott** has recently joined the engineering staff of Morgan Construction Company, Worcester, Massachusetts, where he will be actively associated with the design and production of Morgoil Bearings and other rolling mill machinery.

Following two years at Princeton University, Mr. Endicott entered the Stevens Institute of Technology and was graduated in mechanical engineering with the class of 1915. In the same year he entered the employ of the Morgan Spring Company in their wire mill department. In 1917 and 1918 he was associated with Wickwire Spencer Steel Company at Buffalo. In 1918 to 1926, his services were engaged by the Wickwire Spencer Steel Company as assistant to the Vice President in charge of operations. During the past ten years Mr. Endicott has been engaged in reorganization work and in consulting practice.

GEORGE ENDICOTT

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**L. W. Grothaus** has been elected vice president of Allis-Chalmers Mfg. Co., Milwaukee. He has been associated with Allis-Chalmers for 32 years, first working successively in Norwood shops, the purchasing, drafting, engineering and sales divisions. He served as district sales manager at Minneapolis, and later at Cleveland. In 1925 he was made assistant manager of the electrical division, first at Norwood and later at Milwaukee; in 1931 he was made general representative, and since 1933 has been assistant to the president.

▲

**Harold R. Goodwin,** widely known in the Detroit territory where he has been engaged in the sale of plumbing materials for 20 years, has joined The Youngstown Sheet & Tube Co. sales organization at Detroit.

Mr. Goodwin was associated with the Murray W. Sales Co., Detroit plumbing jobbers, from 1917 to 1924 and with the Kimball-Eisenberg Co., engaged in the same field, from 1924 until recently.

**Frank J. Wood** has just recently been appointed chief engineer of the Industrial Manufacturing Division of the Goodman Manufacturing Co., Chicago, Ill.

At various times in Mr. Wood's career he has been associated with the Crucible Steel Co. as plant engineer; Mesta Machine Co. as rolling mill engineer; with Freyn Engineering Co. as rolling-mill consultant in Russia for a year and previous to his new association with the Western Cartridge Co.

FRANK J. WOOD

**E. T. Bennington,** formerly connected with the Cleveland Tramrail Company has joined the Chicago office of the Harnischfeger Corporation as a sales engineer specializing in cranes and hoists.

## ∴ OBITUARIES ∴

**William P. Gleason,** 71, general superintendent in charge of the construction of the Gary works of the Carnegie-Illinois Steel Corp., and retired superintendent of that plant, died at his home in Chicago, June 14. A native of Chicago, Mr. Gleason became associated with the Illinois Steel Co.'s Joliet works in 1880. In 1887 he became foreman of the machine shop and later was master mechanic of the works. From 1901 to 1906 he was the assistant manager at the Clairton steelworks of the Carnegie Steel Co., Clairton, Pa. In 1906 Mr. Gleason was made superintendent in charge of the building of the Gary, Ind., works. He retired early last year.

▲

**T. Cedar Raleigh,** formerly superintendent of the Cleveland rod mill of the American Steel & Wire Co., died June 24, aged 68 years. He retired on a pension in 1933 after serving the United States Steel Corp. for 52 years. Born in Cleveland, Mr. Raleigh began working at the age of 11 in the Chisholm Steel Works, now the Newburgh Steel Works. He was employed in plants in the Pittsburgh district from 1885 to 1905, when he returned to Cleveland to take the roll mill superintendency.